# The Neurocognition of Linguistic Conflict Resolution:

# Evidence from brain oscillations, ERPs, and source modelling

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*"See first, think later, then test. But always see first.*
*Otherwise you will only see what you were expecting.*
*Most scientists forget that."*
— Douglas Adams

**Declaration**

I declare that this thesis is my own work and was completed under the usual terms of supervision.

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**Abstract**

The ability to express thought in language, to communicate, and to rapidly understand who did what to whom is a highly complex cognitive skill and ultimately the cognitive trait that defines us as being human. For the most part, language comprehension runs very smoothly and people perform it extremely quickly and efficiently. One might think this is nothing exceptional, were it not for the fact that everyday speech contains plenty of ambiguities, speech errors, and otherwise conflicting or interfering information. Similar to any other cognitive system, the language system is fitted out with mechanisms that detect conflicts and trigger compensating adjustments 'on-the-fly' in order to make sense of what has been said. Inevitably, language comprehension requires a combination of automatic and controlled processes and, depending on the context, we engage in both to varying degrees. Historically, linguistic conflict resolution has been investigated regarding to what extent linguistic modules such as 'syntax' and 'semantics' contribute to the process. In this thesis I take a step away from the traditional approach towards the question how the mechanisms underlying linguistic conflict resolution fit into domain-general cognition. It has been shown that controlled processing reliably results in activation of large-scale networks throughout the cortex. Importantly, neuroimaging studies have shown that the crucial brain region that enables us to flexibly make adjustments is the prefrontal cortex (PFC). In this thesis I present four case studies that investigated brain oscillations (as recorded in the EEG and MEG signal) in the time-frequency- (TFR), amplitude-time- (ERP), and source domain to determine how the language system relates to general executive functions. The materials employed structures that are amongst the most well-studied in psycholinguistic research: locally ambiguous garden-path sentences (e.g. "The nurse examined by the doctor was not on duty"), gender-agreement mismatches in anaphora and cataphora (e.g. "The king left London after reminding himself/herself about the letter"/ "After reminding himself/herself about the letter, the king left London."), and syntactically complex

garden-path sentences ("The receptionist realized that the nurse examined by the doctor was not on duty.").

The results in this thesis support the notion that there is indeed a connection between the language system and general executive functions during linguistic conflict resolution. Still, there are also situations where specialized 'modules' perform conflict resolution in a highly automatised fashion, particularly when contextual information sufficiently cues future input. However, as soon as increased uncertainty comes into play or capacity limits are reached, the brain appears to rely on extremely flexible mechanisms in prefrontal cortex regions.

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# 1. Introduction

Successful language comprehension is undoubtedly one of the most challenging cognitive tasks our brain has to manage. This originates from the fact that understanding language requires the speedy and accurate integration of a number of information sources including the retrieval of phonological, syntactic, and semantic information. Once available, this information has to be integrated in the overall sentence or discourse context in order to form a coherent interpretation (e.g. Chomsky, 1965; Chomsky, 1981; Hagoort, 2005; Jackendoff, 2007). Despite its apparent complexity this process appears to be "easy as a pie"- people seem to do it very rapidly and without conscious effort. This in itself should not be surprising - were it not for the fact that language is full of ambiguities, speech errors, and other unexpected conflict-inducing events that need to be resolved in order to make sense of what has been said. Generally speaking, conflicts occur when there is a mismatch between what we expect in a certain context and what we actually observe. When such a mismatch is detected, compensating adjustments are triggered which in turn lead to reanalysis of the input and revision of an initially pursued interpretation (in case of structural ambiguities) or repair processes (when confronted with incorrect input). Prime examples for unexpected conflict-inducing events are the temporarily ambiguous reduced-relative clause in (1) and the semantic violation in (2):

(1) The crook examined <u>by the lawyer</u> turned out to be unreliable.

(2) He spread the warm bread with <u>socks</u>.

When people read or hear a sentence such as (1), they usually experience processing difficulty as soon as they encounter the prepositional phrase (PP) "*by the lawyer*" (e.g. McRae, Spivey-Knowlton, & Tanenhaus, 1998). Coming across the prepositional phrase "*by the lawyer*", it soon becomes clear that the initially preferred

interpretation (*"examined"* as the main verb of the sentence rather than the verb of an embedded clause) is wrong. As a consequence, *"examined by the lawyer"* needs to be reanalysed as a reduced relative-clause modifier of the first noun phrase (NP) *"the crook"*. Attempting to revise the sentence towards a dispreferred syntactic analysis, the reader/listener typically faces processing difficulty. This process has been termed the so-called *"garden-path effect"* (Frazier, 1987). Difficulties arising from local ambiguities as illustrated in (1) have been thoroughly evidenced in e.g. longer reading times in eye-tracking and self-paced reading, and have been used to gain insights into the architecture and mechanisms of the language processing system (e.g. Clifton et al., 2003; Ferreira & Clifton, 1986; Fodor, Bever, & Garrett, 1974; Frazier, 1987; Trueswell et al., 1994).

By contrast, the processing difficulty elicited by *socks* in sentence (2), compared to a plausible sentence ending such as *butter*, can be attributed to the fact that *socks* semantically mismatches the preceding context. Processing difficulties associated with lexical-semantic mismatches equally lead to longer reaction and reading times. Consequently, quantitative measures make it difficult to differentiate between the mechanisms underlying different linguistic "modules" (i.e. syntax and semantics) during language comprehension.

Over the last four decades, psycholinguistic research has seen increasing interest in neurocognitive methods to study the time-course of different facets of language processing. Electrophysiological measures have proven to be extremely suitable to clarify the neural mechanisms of language processing, as they enable us to isolate qualitatively different processing mechanisms while tracking language comprehension in real time (e.g. Kutas, Van Petten & Kluender, 2006).

Traditionally, syntactic conflicts were linked to a late positive event-related brain potential (the "P600"; Osterhout & Holcomb, 1992; Hagoort, Brown, & Groothusen, 1993), because syntactically ambiguous sentences (Osterhout and Holcomb, 1992; Osterhout et al., 1994; van Berkum et al., 1999a) as well as syntactic violations (Hagoort et al., 1993) reliably elicited this component. Contrary to that, lexical-semantic conflicts in sentence contexts were associated with modulations of a centro-parietal negative-going wave, which peaks approximately 400ms after stimulus onset (the "N400", Kutas & Hillyard 1980; Hagoort and Brown, 1994). Interestingly, an N400 has not only been observed when a word semantically mismatches its sentence context, but also for a broader discourse context (e.g. van Berkum et al., 2003), and even when the context consists of a single word (Brown and Hagoort, 1993). These ERP effects have been replicated many times, which inevitably led to the belief that the P600 and N400 represent distinct markers which might even be *diagnostic* for syntactic and semantic processing, respectively.

To date, five ERP components play a key role in the sentence processing literature: the early left anterior negativity (ELAN), the left anterior negativity (LAN), the N400, the auditory MMN, and the P600. I will discuss the language-related ERP components and their interpretation in more detail in section 2.1.

## 1.1 Influential neurocognitive models of sentence processing

### 1.1.1 The neurocognitive model of auditory sentence comprehension (Friederici, 2002)

In line with Frazier's influential (syntax-first) garden path model (Frazier, 1987), Friederici (1995, 2002) proposed a three-stage neurocognitive model of sentence comprehension (based on the Wernicke-Geschwind model (Kandel et al., 1995, Chapt.34). This model defines temporal parameters of sentence comprehension, which are based on electrophysiological data and neurotopographical brain-imaging data. The most defining characteristics of this model is that it temporally orders syntactic processing (phase 1) and semantic processing (phase 2), before integrating both information sources in phase 3. Friederici suggested that the ERP components identified in the sentence processing literature are consistent with this three-stage architecture. Although this model is mainly in line with a *syntax-first* parsing architecture (Frazier, 1987; Frazier and Rayner, 1982), Friederici argued that her proposed model is also compatible with interactive models of language comprehension, in that they just represent different processing phases during language comprehension. The three phases of the model are defined by the following temporal parameters:

Phase 1 (100-300ms from word onset) denotes the time interval in which the currently encountered word is provisionally integrated into the syntactic representation of the sentence. More precisely, the parser incrementally assigns the initial syntactic structure based on word-category only (i.e. no semantic information is used for structural parsing at this stage). Phase 2 (300-500ms) involves morpho-syntactic processing and the semantic integration of the word; during this phase the parser tries to build thematic role assignment. Finally, during Phase 3 (500-1000ms), the various sources of information are brought together. This is also the stage where

repair or reanalysis processes take place, if required. As described before, semantic processes evoke a negative waveform peaking around 400ms after word onset – the *N400*. Typically, the amplitude of the N400 is increased whenever a word cannot be integrated into the preceding semantic or pragmatic context (Phase 2). The primary verification for the temporal structure of Friederici's model originates from the temporal ordering of the ERP components itself: an early left anterior negativity (*ELAN*) occurring between 100-300ms, a left anterior negativity (LAN) taking place between 300-500ms, and a late centro-parietal positivity, the *P600* (Osterhout & Holcomb, 1992), which peaks between 600-1000ms (Phase 3). In line with Fodor & Inoue's (1994) diagnosis model, Friederici (2002) argues that syntactic error detection is primarily reflected in the early components (LAN or ELAN) whereas syntactic repair corresponds to the 'late' P600 component.
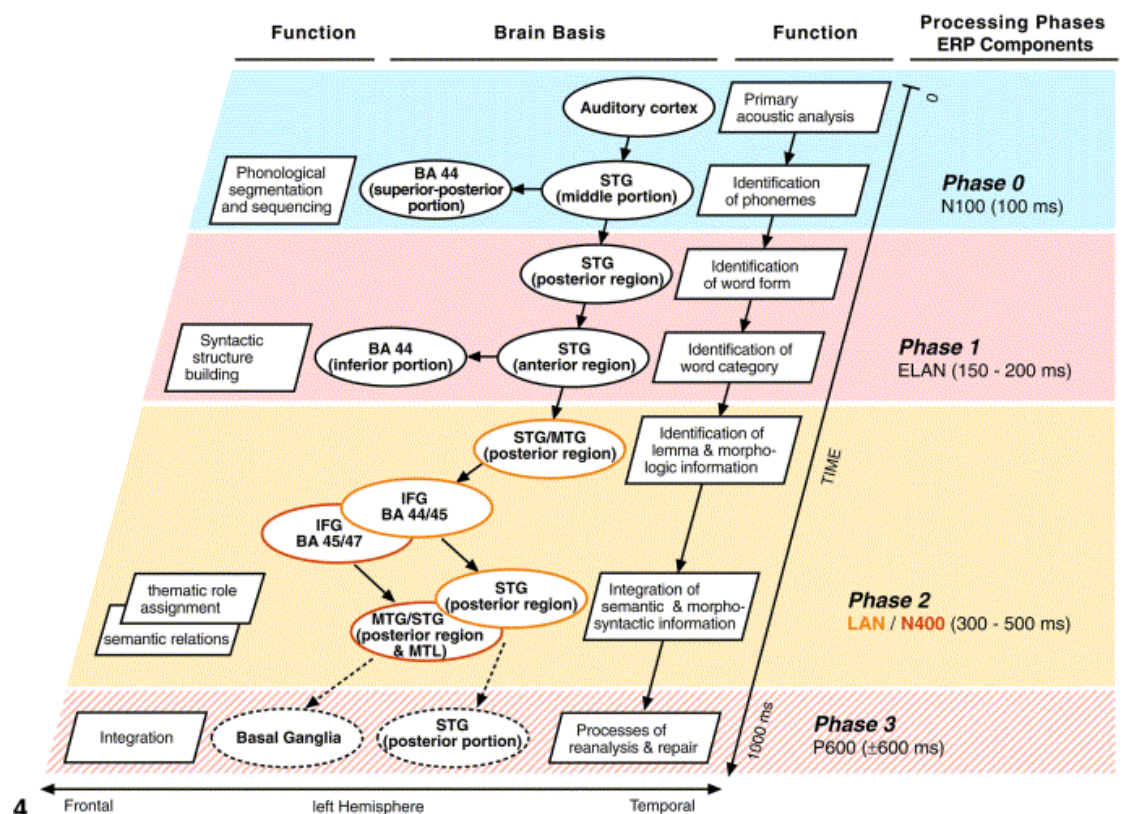


*Figure 1: The Neurocognitive model of auditory sentence processing (Trends in Cognitive Sciences Vol.6 No.2, 2002)*
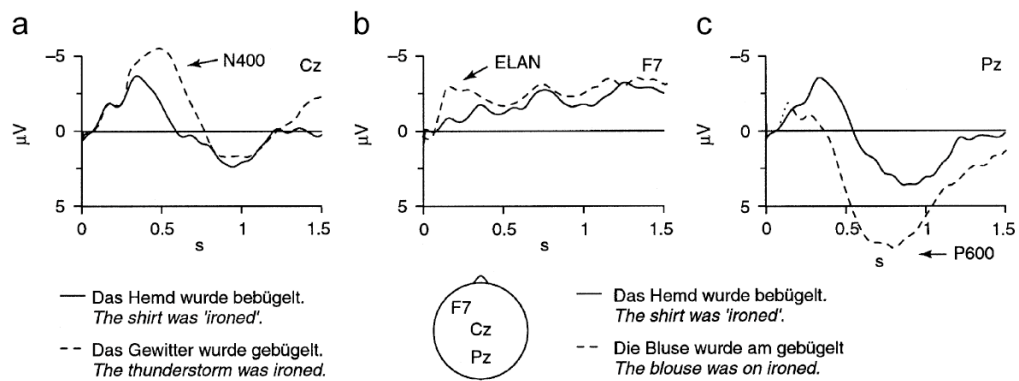
*Figure 2: The main language-related ERP components associated with the three stages of Friederici's model at three representative electrodes: Comparing a grammatical control sentence and a sentence containing a semantic violation elicits the N400 (a). A comparison of a grammatical sentence and a syntactically anomalous sentence reveals representative instances of the ELAN (b) and the P600 (c). This figure is adapted from Fig. 3 in Friederici (Trends in Cognitive Sciences Vol.6 No.2, 2002)*

Friederici claims that a bilateral fronto-temporal network supports these three processing stages (**s**ee Gaskell, 2007 (Oxford Handbook of Psycholinguistics): Word-category structure building (phase 1) is assumed to activate anterior regions of the left superior temporal cortex and the left frontal operculum. Phase two is assumed to engage the mid left superior temporal gyrus (STG), the middle temporal gyrus (MTG), and the left inferior frontal gyrus (IFG, BA45/47) for semantic relations, while syntactic relations left lateral activate BA44 and the frontal operculum. The integration of syntactic and semantic information in phase three has been claimed to activate the posterior portion of the left STG. With respect to right hemisphere contributions to sentence processing, Friederici argues that prosody is supported by the posterior right STG and the right frontal operculum. To sum up, the right hemisphere maintains prosodic processing and the left hemisphere supports syntactic and semantic comprehension. Interaction between these processing streams is carried out via the corpus callosum.

**1.1.2 The Memory, Unification, and Control (MUC) Framework** (Hagoort 2003, 2005)

In contrast to Friederici's neurocognitive model of sentence processing where different processing levels are strictly autonomous and bottom-up, Hagoort's MUC (Memory, Unification, Control) framework (2003, 2005, 2009; based on a computational model of parsing developed by Vosse and Kempen (2000)) adopts a parallel architecture (Jackendoff, 1999; 2002), arguing for the interactivity of syntax and semantics. Based on this, Hagoort suggests a different account of parsing as compared to Friederici, in that there is only one parsing process, the *unification*, which operates on syntactic, semantic, and phonological information simultaneously. The basic units of the unification framework are lexicalized chunks of syntactic structure: each word is stored in the *mental lexicon* (e.g. Levelt et al., 1999) as part of a syntactic frame containing information about the structure in which the word can appear (in addition to a semantic frame and a phonological frame). There are two central operations necessary to build representations in the unification framework: *lexical retrieval* (i.e. access lexical material from the long-term memory) and *unification* (i.e. the process of combining two syntactic frames together). Much as with tree-adjoining grammars (Joshi & Schabes, 1997) the smallest syntactic units are words with associated syntactic frames. Subsequently syntactic unification combines these small trees together. Already during the earliest stages of the parsing process, syntactic and semantic information are assumed to be highly interactive. Similarly, unification processes are assumed to operate in parallel on syntactic, semantic, and phonological levels. When faced with structural ambiguities, two (or more) competing frames are accessed simultaneously. Based on various contextual factors (e.g. frequency, plausibility, etc.), a lateral inhibition process is triggered and the 'winner-takes-it-all', returning a single phrasal structure.

The brain area that appears to play a key role in storage and retrieval of linguistic information from long-term memory is the left temporal lobe (Brodmann area (BA) 21). Besides phonological and phonetic feature, also syntactic properties such as grammatical gender, word class, as well as the syntactic frames are assumed to be retrieved from there. More precisely, the central to posterior temporal gyrus (STG) and the superior temporal sulcus (STS) have been shown to be activated by phonological / phonetic features (e.g. Indefrey & Cutler, 2004), while lexical-semantic properties have been linked to the left middle and inferior temporal gyri (e.g. Damasio, 1996; Hickock & Poeppel, 2000). The prime candidate for the unification process is the left inferior frontal gyrus (LIFG), particularly BA 44 and BA 6 (phonological unification), BA 45 and 44 (syntactic unification), and BA 45 and BA 47 (semantic unification). Although these regions have historically been described as inherently linguistic (*Broca's area*), note that Hagoort's MUC model acknowledges the fact that these areas also subserve non-linguistic, domain-general functions.

The MUC's *control* component becomes important under circumstances where verbal action planning and attentional control is needed, for instance during turn-taking in conversations and in bilingualism, when one has to chose the correct target language. Studies investigating verbal control using Stroop tasks (e.g. Botvinick, 2001; Roelofs & Hagoort, 2002) have shown that the main brain areas regulating control are the anterior cingulate cortex (ACC, BA 24/32), and the dorsolateral prefrontal cortex (dlPFC, BA 46/9).
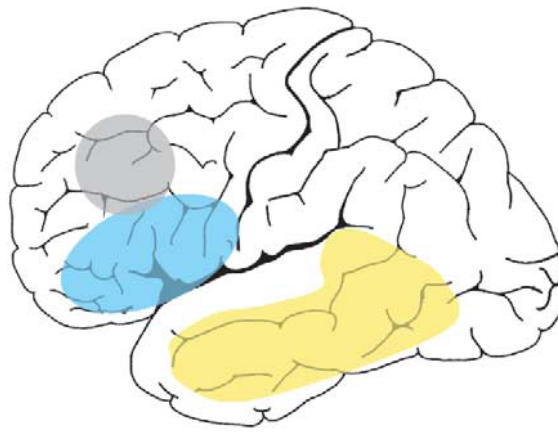
*Figure 3: The MUC model projected onto a lateral surface of the left hemisphere: Memory (yellow) in left temporal cortex. Unification (blue) in LIFG, and Control (grey) in dorsolateral prefrontal cortex. The anterior cingulate cortex (ACC: part of the Control component) is not shown here. TRENDS in Cognitive Sciences, Vol.9 No. 9, September 2005.*

Compared to Friederici's model, the ERP components do not reflect distinct processing stages, but rather different aspects of the unification process. In other words, the MUC ascribes ERP components to a binding mechanism between lexical frames. While the ELAN reflects impossible unification between two structural frames, the LAN represents failed unification of morphosyntactic mismatches, for instance agreement mismatches, *after* two syntactic frames have been combined. Contrary to Friederici's view that the P600 is a marker of revision or repair (due to invalid or unattainable unification), Hagoort interprets it as an index of the *difficulty* of unification. More specifically, the P600 is assumed to reflect the time required to establish the bindings. This view might explain why so many different types of perfectly grammatical sentences, i.e. syntactically complex sentences and structural ambiguities, elicit this ERP component. The N400, which is assumed to occur in parallel to syntactic unification, stands for lexical-semantic unification (Hagoort, 2003; see also Sprouse & Lau, 2012). By contrast to Friederici's serial / hierarchical model that assumes priority of syntactic computation or *syntax first mechanism*, Hagoort's MUC is fully parallel, implying that any kind of information (word category, argument structure, semantics) is used as soon as it becomes available (e.g. beim Graben et al, 2008).

## 2. Neurophysiological measures: Event-related potentials / fields

Event-related potentials (ERPs) in the on-going EEG are a non-invasive method to measure brain activity during cognitive processing by picking up small electric currents through the skull and scalp. More precisely, ERPs represent the sum of postsynaptic activity of multiple neurons, which are time-locked to a certain stimulus onset (e.g. the presentation of a word, a sound, or an image) (Luck, 2005). These short-lived electric potential shifts, which become visible by averaging across many trials to a time-locked stimulus, are the so-called *ERP components* (to obtain an accurate estimate and to improve the signal-to-noise ratio, at least 40 trials per condition are necessary). As opposed to behavioural measures such as response- and reading times, ERPs are characterized by various measurable dimensions: Each ERP component is said to reflect one or more cognitive operations and is defined by *polarity* (*negative* or *positive*), *amplitude*, *scalp distribution*, and *latency*. Therefore, modulation in any of those dimensions may ultimately be used to identify and distinguish neural processes underlying complex cognitive, sensor, or motor tasks. Unlike other neurocognitive methods as for example fMRI (even Event-Related fMRI), ERPs provide an extremely high time resolution in the range of one millisecond. Due to this, ERP-analysis offers an excellent opportunity to study the on-line mechanisms of linguistic error detection and repair.

Berger first described the EEG technique in 1929 and claimed that EEG would provide a "window to the brain" (Berger, 1929). Since then, many advances in EEG recording technology and EEG analysis methods have been made which make EEG a powerful non-invasive brain-imaging tool which has besides its excellent temporal also a quite reasonable spatial resolution.

In addition to the electric currents that are recorded by the EEG, the brain produces small magnetic fields that can be measured non-invasively by the magnetoencephalogram (MEG). MEG provides the same temporal accuracy as EEG while the spatial resolution is significantly enhanced. Analogous to the ERP technique, epochs of the MEG that are time-locked to a stimulus can be averaged to extract the event-related magnetic field (ERF). The main advantage of magnetic fields as opposed to evoked potentials is that they penetrate the skull without impedance while evoked potentials are significantly distorted by the resistive properties of the skin, skull, and cerebral fluids, which act as a low pass filter (e.g. Ikesawa et al, 2011). Consequently, the scalp-distribution of the ERFs enables a fairly accurate estimate of the spatial extent (0.1–1 cm) and temporal dynamics (1ms) of neuronal assemblies underlying cortical activity which make the anatomical origins of the magnetic signals easier to localise (Frye et al., 2009; Hämäläinen, Hari, Ilmoniemi, Knuutila, & Lounasmaa, 1993). However, MEG is less sensitive to cortical sources that are located far away from the scalp, because the magnetic signal shows a steeper decline with increasing distance.

During the last decades plenty of psycholinguistic studies have used electrophysiological techniques in order to offer insights about the functional organisation of language and its brain bases in real-time (see Kutas et al., 2006 for review). Most of these studies have confirmed that ERPs / ERFs reveal qualitatively different brain responses in relation to syntactic and semantic anomalies such as the (E)LAN, the N400, the P600, and the auditory MMN, which are now generally associated with certain aspects of language processing. However, many of these inherently language-specific components have also been observed in relation to non-linguistic stimuli (e.g. Niedeggen & Rösler, 1999). Consider for instance the N400 component: the N400 has also been shown to be sensitive to incongruous solutions in multiplication problems (Niedeggen & Rösler, 1999), incongruity processing with

regard to faces (Jemel et al., 1999), and environmental sounds (Van Petten & Rheinfelder, 1995). Nevertheless, language-related ERP components have been proven beneficial in understanding not only how language processing takes place e.g. in children and adults, in language disorders as well as in normal processing, but they also gave insights with regard to neurocognitive model building (e.g. Friederici, 1995, 2002; Bornkessel, 2002; Hagoort, 2004). Importantly, such electrophysiological evidence seems to generalize across languages (English, German, Dutch, Italian, French; Angrilli et al. (2002); Friederici (1999); Hagoort et al. (1993), Osterhout et al. (2003)), across presentation modalities (visual and auditory) and word presentation rate (Hagoort & Brown (2000), Holcomb & Neville (1991); Osterhout & Holcomb (1992); Allen, Badecker & Osterhout (2003)). The following section will give a brief overview of the event-related brain potentials elicited during language comprehension.

## 2.1 The Neurocognition of Language Processing

## 2.1.1 ELAN

The ELAN (early left anterior negativity) was first reported in 1991 by Neville and colleagues in response to phrase-structure violations in which prepositions such as *"about"* in sentence (b) occurred in ungrammatical positions (cf. Sprouse & Lau, 2012):

(3a) The boys heard Joe's story *about* Africa.

(3b) *The boys heard Joe's *about* stories Africa.

The ELAN component refers to a negative-going deflection with a peak in a relative early processing window (100-250ms after stimulus onset). Crucially, this very specific response to phrase structure violations appears to generalise across languages

including English, Spanish, French, and German (e.g. Dikker et al., 2009; Isel et al., 2007; Friederici et al., 1993; Friederici, 2002; Lau et al., 2006).

ELANs have almost exclusively been illustrated in relation to outright phrase structure violations, but not with the processing of infrequent syntactic structures (Friederici et al., 1996; Hagoort et al., 1993). Moreover, it has been claimed that early left negativities are specific to the processing of word-category information and syntactic structure building (Friederici, 1995; Friederici et al. 1996). Lately, the functional interpretation of the ELAN as index of local syntactic structure building has been challenged because it has been shown that agreement violations elicit an ELAN as well (Hasting and Kotz, 2008).

In recent years there has been a shift in the interpretation of the ELAN focusing on the extreme early latency of this ERP component (sometimes between 100-160ms post-stimulus). This speedy, syntactic-driven response is so startling because it seems to be inconsistent with early sensory processing (Dikker et al., 2009). Given the assumption that the extremely early ELAN is supposedly a marker of high-level linguistic operations such as phrase-structure building, Lau et al. (2006) suggested that the ELAN is linked to predictive processing: According to this, the parser has already anticipated the critical word including its syntactic features and 'pre-parsed' prior to actually encountering it. Following this, Dikker et al. proposed in 2009 the "sensory ELAN hypothesis", where the ELAN represents a processing phase prior to lexical access, which is assumed to be localized in the sensory cortices (visual or auditory cortex). Under the view that the ELAN represents a sensory response, linguistic predictions become available to sensory cortices via top-down modulation. More precisely, the sensory cortices evaluate the probability of individual phonetic forms to decide whether the incoming word is most likely a verb, noun, etc.

Lately, many studies have questioned the reliability and validity of the ELAN component, mostly arguing that these effects result from filter artifacts and so-called baseline problems (cf. Steinhauer, 2011).

## 2.1.2 LAN

Although the LAN and the N400 share the same polarity (i.e. *negativity*) and latency range (between *300ms* and *500ms post-stimulus onset*), they are fundamentally different with respect to the events they respond to: in contrast to the N400 the LAN is more strongly related to *syntactic processing* than to semantic integration (Osterhout & Holcomb (1992); Kluender & Kutas (1993); Münte et al (1993); Rösler et al (1993); Friederici et al. (1996)). Most commonly, the LAN has a frontal scalp distribution and is often largest over the left hemisphere, although sometimes is has been shown to be bilateral. Left anterior negativities have been reported in response to agreement violations, for instance morpho-syntactic errors such as incorrect inflection (Coulson et al., 1998; Friederici et al., 1993; Gunter et al., 2004; Osterhout & Mobley, 1995), phrase structure violations (Friederici et al., 1993, 1996; Münte, Heinze, & Mangun, 1993; Neville et al., 1991; Osterhout & Holcomb, 1992), in correlation to the processing of subcategorization information (Osterhout & Holcomb, 1993; Rösler, Friederici, Pütz, & Hahne, 1993), for violations of word-category constraints (Münte et al., 1993; Friederici et al., 1993; Hagoort et al., 2003),  and even in response to syntactic garden-path sentences (Kaan & Swaab, 2003). In addition to this, LAN effects have also been described with the processing of fully grammatical filler-gap dependencies containing no violations and have therefore been suggested to reflect working memory load (Hahne & Friederici, 1999; Kluender & Kutas, 1993; King & Kutas, 1995). This has raised the debate whether the LAN is a specific response to 1) morpho-syntactic ill-formed expressions, and/or whether it can be 2) a marker of general working memory processes. In line with Friederici's model, supporters of the

first account suggest that the LAN reflects difficulties in thematic role assignment based on grammatical information such as morphological properties (person, number, gender, and case features). Under the working memory view, the LAN indicates a "search" forward, e.g. fillers looking for suitable gaps (Kluender & Kutas, 1993; see Kutas, van Petten, Kluenders, 2006 for review) as well as a backwards checking when unexpected information is encountered and needs to be revised and combined with earlier information in the sentence, for instance anaphora looking for suitable antecedents (e.g. Coulson, King, & Kutas, 1998; van Berkum, Brown, Hagoort, & Zwitserlood, 2003) or verbs searching for acceptable subjects (King & Kutas, 1995; Vos, Gunter, Kolk, & Mulder, 2001).

### 2.1.3 N400

The first discovered and now well-established ERP component is the N400 (Kutas & Hillyard, 1980), a negative going waveform starting around 250ms after the critical word-onset and peaking at approximately 400ms. This component represents a transient modulation of the EEG in response to the onset of a meaningful auditory or visual stimulus (e.g. a content word or a picture), and has been proven to be especially sensitive to semantic manipulations. The better a word matches semantically with its surrounding context, the more reduced is the amplitude of the N400. Modulations in the amplitude of the N400 were first shown when the meaning of a word (e.g. "socks") mismatched the overall meaning of its sentence context as illustrated in the nowadays-famous sentence "He spread his warm bread with socks." (Kutas & Hillyard, 1980). Kutas and Hillyard predicted that these manipulations would elicit a P300, a positive going ERP component peaking around 300ms after stimulus onset, which had been shown to be sensitive to the processing of unexpected events in a wide variety of types (e.g., Duncan-Johnson & Donchin, 1977; Ruchkin, Sutton, &

Tueting, 1975). Surprisingly, compared to semantically expected sentence endings such as "butter" in the example above, the semantically unexpected sentence endings elicited a negative going wave peaking around 400ms with a centro-parietal scalp distribution. During the following years it became evident that the N400 is also affected by a variety of factors other than "pure" semantic violations: Words that are in consensus *within* a sentence but somehow *unpredictable* can elicit a more negative N400 (Kutas & Hillyard, 1984). This was the case for a sentence like *"He mailed the letter without a thought."* compared to a more expected *"He mailed the letter without a stamp."*. In addition to this, van Berkum, Hagoort and Brown (1999) demonstrated that words, which perfectly fit their sentence context but which cannot be integrated in the global discourse context, modulate the N400 component. In later years, Hagoort et al. (2004) have suggested that if a sentence fails to verify against world knowledge the N400 amplitude is affected in a similar way. They illustrated that "white" in "The Dutch trains are white…" elicits a N400 in Dutch readers as it violates their real-world expectations (i.e. Dutch trains are in fact *yellow*). By contrast, some have suggested that the N400 reveals the ease with which information can be accessed from semantic memory (Kutas and Federmeier, 2000; Federmeier and Lazlo, 2009). The scalp distribution of the N400 is mostly over posterior sites and, at least for written input, appears to be larger over the right hemisphere. For spoken input however, no such lateralization has been evidenced (Hagoort et al., 2003).

Following the discovery of the "semantic" N400, a number of language related ERP studies have tried to identify ERP components that are linked to syntactic processing. The most prominent syntax-related effects are a (early) left-anterior negativity or (E)LAN and a centro-parietal positivity, also referred to as P600 or SPS.

**2.1.4 P600 / SPS**

Another ERP component, which has been strongly tied to syntactic processing is a late, positive going wave with a centro-parietal scalp distribution. This component is referred to as the P600, the syntactic positive shift (SPS), and the late positive component (LPC), and was first reported by Osterhout and Holcomb in 1992 (see Gouvea et al., 2010 for review). They described a large positive waveform peaking approximately 600ms after the onset of words that mismatched the expected syntactic structure in garden-path sentences such as *"The broker persuaded to sell the stock was sent to jail."*. Slightly after that, Hagoort, Brown and Groothusen (1993) found that outright syntactic agreement violations (e.g. *"The child throw the toys on the floor."*) evoked a similar late positivity. According to its latency and polarity, Osterhout and Holcomb referred to this effect as the P600, whereas Hagoort and colleagues used its functional characteristics to describe it as the syntactic positive shift. The term LPC represents a generic term: it covers late centro-parietal positivities including the P300, P3b, and the P600 and is - in relation to language processing research - typically only used when referring to studies that investigate priming (e.g. Van Petten et al., 1991). Simply speaking, the P600 / SPS / LPC is typically observed whenever a violation of a syntactic constraint renders the sentence ungrammatical. Research following the discovery of the P600 / SPS has illustrated that various kinds of syntactic violations elicit this effect: Within sentences, phrase structure violations (Friederici et al., 1996; Neville, Nicol, Barss, Forster, & Garrett, 1991), violations of subcategorization (Osterhout et al., 1994; Osterhout, 1997), subjacency violations (Neville et al., 1991), and violations of number, gender, tense, and case agreement (e.g. Allen, Badecker, & Osterhout, 2003; Coulson, King, & Kutas, 1998; Friederici, Pfeifer, & Hahne, 1993; Gunter, Stowe, & Mulder, 1997; Hagoort et al., 1993; Osterhout & Mobley, 1995; Münte, Szentkui, Wieringa, Matzke, Johannes, 1997; Nevins, Dillon, Malhotra, &

Phillips, 2007) reliably modulate the P600. Nonetheless, the P600 is not only a reflection of syntactic anomalies: a number of studies have reported P600-type responses to perfectly well formed, syntactically complex sentences such as long-distance *wh*-dependencies (Felser, Clahsen, & Münte, 2003; Fiebach, Schlesewsky & Friederici, 2002; Kaan et al. 2000; Phillips, Kazanina, & Abada, 2005).

One of the most influential studies that reported a late positivity to congruous sentences is Kaan et al. (2000). They reported a centro-parietal positivity to words that were complex, although syntactically correct such as the verb *imitate* in (4a) as compared to a preferred continuation of the preceding sentence fragments as illustrated in (4b).

(4a)    Emily wondered *who* the performer in the concert had <u>imitated</u> for the audience's amusement.

(4b)    Emily wondered *whether* the performer in the concert had <u>imitated</u> a pop star for the audience's amusement.

Sentence (4a) is more complex than (4b) as it represents a long-distance filler/gap dependency: The *who*-clause (*filler*) has to be related to the verb *imitate* or more precisely, to an "empty" position (*gap*) at the verb in order to be interpreted as its direct object. Kaan and colleagues used this result to argue against the interpretation of the P600 as a reflection of *repair* or *revision*. Mostly, the term *revision* is used to refer to the processes involved in yielding a correct analysis when the linguistic input contains a syntactically correct but non-preferred continuation of an ambiguous sentence fragment. Contrary to that, *repair* refers to mechanisms underlying the attempt to build a representation of a sentence when a sentence continuation is ungrammatical under all possible analyses of the initial sentence fragment and cannot under any circumstances result in a syntactically correct analysis. The exact nature of

the mechanisms that underlie the processes of revision and repair is a matter of debate (Fodor & Ferreira, 1998).In line with Gibson (1998) they suggested that the P600 reflects demands on working memory by relating the *wh*-phrase over several intervening words to the verb and therefore proposed the P600 as a marker of 'syntactic integration difficulty'.

What is common to all of these violation / complexity – induced P600s is that the effect starts to emerge around 500ms after the critical word onset and persists up to 500ms (the P600 is typically found within a latency range of 500ms to 800ms, sometimes even up to 1000ms after stimulus onset). Surprisingly, some studies suggested that the amplitude of the P600 can be modified by lexical as well as semantic contextual constraints (Osterhout, 1994; Gunter, Friederici and Schriefers, 2000) and in relation to thematic role assignment (Kuperberg et al., 2003; Van Herten et al., 2005; Kim & Osterhout, 2005; Wassenaar & Hagoort, 2007). For serial models of sentence comprehension, the P600 reflects *reanalysis and revision processes* of a syntactic structure that has been derived in an early stage of processing based on minimal constraints (Ferreira and Clifton, 1986; Frazier, 1987; Friederici, 1995). As constraint-based models assume a single stage of parsing, the P600 is said to reflect *difficulties of syntactic integration* once syntactic frames had been activated and modified by different sources of information (Ferreira & Clifton, 1986; Frazier, 1987; Fiebach et al., 2002; Kaan et al, 2000). By contrast, Hagoort (2003; 2004; 2005) suggested that the P600 is a reflection of difficulties in syntactic unification, implying that the amplitude of the P600 is affected by competition between alternative unification options. More recently it has been suggested that the P600 indicates a monitoring process triggered by a conflict, e.g., when an unexpected linguistic item occurs where another item is highly expected (Kolk, Chwilla, Van Herten, & Oor, 2003), implying that the P600 is an index for domain-general cognitive control processes. A newer but rather intriguing theory entertains the idea that the late

positivity is possibly triggered by expectancy violations and not a reflection of syntactic rule violations. More specifically, the P600 may be the result of preactivating information that is invalidated by the actual input stream, e.g. when expectations of upcoming words are disconfirmed (e.g. DeLong et al, 2011; Federmeier et al., 2007; Otten and van Berkum, 2008; van de Meerendonk et al., 2010; Thornhill & van Petten, 2012).

### 2.1.5 MMN (mismatch negativity) or MMF (mismatch field)

Similarly to the ELAN, the MMN is considered an automatic brain response, which is typically elicited by the deviation of a physical stimulus from a preceding stimulus in an otherwise regular input sequence. Although the MMN can be triggered in any kind of sensory system by presenting a deviant stimulus in a repetitive input sequence, it is typically elicited by acoustically differing stimuli (Näätänen et al, 1978). The MMN is typically reflected as a fronto-central negativity, approximately occurring in the latency range of 100–250ms. When a nose reference is used, the MMN undergoes a phase reversal (i.e., positive polarity), with a surface distribution over the mastoids and other lateral posterior sites in the same latency range. Although the MMN and its magnetic field counterpart (MMNm) is not a traditional "language" component, in recent years it has been increasingly used to study syntactic processing (cf. Kotz, 2008). The MMN is typically modulated by agreement violations across many languages, for instance in English, Finnish, and German (Pulvermüller and Shtyrov, 2003; Shtyrov, Pulvermüller Näätänen & Illmoniemi, 2003; Hasting, Kotz & Friederici, 2007).

## 2.2 The problems with ERPs

Recent evidence suggests that a one-to-one mapping of ERP components and specific domains of linguistic processing cannot be upheld (cf. Röhm, 2004; Kos et al, 2010; Frenzel et al, 2011): Conflicts that are supposedly syntactic in nature elicited N400-like effects (e.g. Bornkessel, McElree, Schlesewsky, & Friederici, 2004; Choudhary, Schlesewsky, Roehm, & Bornkessel-Schlesewsky, 2009; Haupt, Schlesewsky, Roehm, Friederici, & Bornkessel-Schlesewsky, 2008; Weber and Lavric, 2008). Similarly, studies that explicitly manipulated semantic features such as world-knowledge violations (e.g. "De kat die voor de muizen vluchtte… "(The cat that fled from the mice…) (Kolk et al., 2003) and "The pizza had been delivering…" (Kim and Osterhout, 2005)), or violations of semantic-thematic knowledge (e.g. "Every morning at breakfast the eggs would eat…" (Kuperberg et al., 2003)), elicited a P600 in place of the expected N400 effect (the "semantic" P600). However, these semantic P600s have still been linked to processes similar to those underlying regular "syntactic" P600, for instance reanalysis, "re-attending", and extended analysis of problematic sentences (e.g. Kuperberg, 2007).

In view of this, several neurocognitive models of language processing have tried to address this puzzle, particularly with respect to the P600 component (cf. Kos, 2011). The extended argument dependency model (eADM) (Bornkessel and Schlesewsky, 2006; Bornkessel-Schlesewsky and Schlesewsky, 2008, 2009) and the Monitoring Theory (Kolk et al., 2003; van Herten et al., 2005, 2006; van de Meerendonk et al., 2009, 2010) relate the P600 to *domain-general mechanisms* of monitoring and cognitive control (labelled *generalized mapping* in the eADM). Hagoort and colleagues propose in their MUC framework that strong cues on one

processing level drive the processing cost on another level, which in turn may lead to unexpected ERP components.

One major drawback of ERPs is their limited value for exploring the processes involved in large-scale synchronization of different and often quite distributed brain areas. Another problem is that the same ERP surface component can be generated by different underlying sources (the so-called inverse problem; e.g., Nunez, 1981): Given the localization of an electric field on the surface, the question of finding the dipolar origin of this surface effect can have almost infinite solutions. An answer to both these questions as well as the uncertainty related to conflict-induced ERP component may be found in the patterns of synchronization and desynchronization of neuronal activity, and the localization of this activity. Typically, brain oscillations are divided into different frequency bands, ranging from low frequencies such as delta (0.5-3.5Hz), theta (4-7 Hz), and alpha (8-12 Hz) up to the higher frequencies of beta (12-30 Hz) and gamma (> 30 Hz). It has been shown that the synchronization and desynchronization of neuronal activity is related to the coupling and uncoupling of functional networks in the brain (see e.g. G. Pfurtscheller & Berghold, 1989; G. Pfurtscheller & Lopes da Silva, 1999; G. Pfurtscheller & Neuper, 1997; Singer, 1993, 1999; Varela et al., 2001). More precisely, assemblies of neurons that belong to one and the same functional network can be identified because they fire synchronously in a certain frequency range. Recent evidence in the language domain (e.g. Bastiaansen & Hagoort, 2006) suggests that ERP components can be differentiated based on the analyses of activity-changes in distinct frequency bands (in terms of power change and/or phase locking) and their underlying dynamic behaviour. Moreover, they may be valuable with regard to the functional organization of the language comprehension system and its ingrained complexity.

**2.3 Neuronal brain oscillations**

There are two ways of analysing the on-going activity in the EEG or MEG signal: Besides analysing the activity in the time domain using the ERP-technique described above, one can also analyse activity in the frequency domain by analysing oscillations in various frequency bands. Oscillatory components that are present in the EEG / MEG signal often show power changes in relation to experimental events (Tallon-Baudry and Bertrand, 1999). As these signals are time-locked but not necessarily phase-locked, they will not be represented in event-related potentials and fields due to signal averaging during the ERP analysis. Oscillations in different frequency bands are functionally related to cognitive processing and behaviour and, above that, are assumed to be the key to understand functional communication in the brain (Klimesch et al., 1999; Pfurtscheller & Lopes da Silva, 1999). A number of studies have shown that long-range inter-area communication of distributed brain systems is reflected in synchronized oscillatory activity (Gross et. al, 2004). Neuronal synchronization refers to the coupling and uncoupling of functional networks in the brain (see, e.g., Varela, Lachaux, Rodriguez, & Martinerie, 2001; Pfurtscheller & Lopes da Silva, 1999b; Singer, 1993, 1999; Pfurtscheller & Neuper, 1997). Synchronous, repetitive firing of neurons speeds up the activation of functional networks and, as a result, increases the probability that neurons join in synchronous firing (e.g., Koenig & Schillen, 1991). Neuronal assemblies belonging to the same functional network are identifiable as such because they fire synchronous in a certain frequency range. Long-range synchronization in various frequency bands is consequently assumed to be important to functionally link distributed brain areas that partake in the same functional network and to integrate local information (Singer & Gray, 1995; Gray, Konig, Engel, and Singer (1989)). Others have argued that synchronous oscillations are particularly crucial in top-down processing (e.g., Engel, Fries, & Singer, 2001; Tallon-Baudry & Bertrand, 1999) or in a large- scale integration of bottom-up and top-down processes (Varela et al., 2001). To estimate synchronous co-

activation between MEG / EEG sensor sites, coherence is typically used as a measure (for methodological details see Nunez et al., 1997, 1999; Rappelsberger, 1998). Some have proposed that ERPs are nothing but a result of superposition of oscillations in different frequency bands, which engage in transient phase locking (e.g., Makeig et al., 2002; Basar et al. 2001), while others have argued that this claim is too extreme (Bastiaansen, 2005).

Neuronal oscillations have been studied for almost a century now, but only recently has their functional significance been studied systematically (Gray 1994; Engel et al. 2003). It has been suggested that brain oscillations are of fundamental importance for mediating and distributing "higher-level" processes in the human brain (Klimesch 1999; Basar et al. 2001c). Theta oscillations (4-7Hz) for instance have been shown to influence neural network activity in many ways and, and are important for successful performance in a variety of cognitively demanding tasks, particularly when faced with conflicting information (Botvinik, 2001).

### 2.3.1 Basic concepts of neuronal oscillations

In 1992, Galambos proposed a classification scheme to distinguish three types of brain oscillations, which was originally based on the gamma frequency band (> 30 Hz):

a) Spontaneous oscillations are oscillations that are *not* stimulus-locked and are often described as background noise.

b) Evoked oscillations are time-locked *and* phase-locked to a certain event.

c) Induced oscillations are time-locked to a certain event but not phase-locked.

There have been considerable discussions whether evoked and induced oscillations occur independently of each other or whether they represent different instances of the

same event, as they both originate from spontaneous oscillations, which are modulated in response to stimulus processing (cf. Röhm, 2001). Both can be extracted by trial-averaging and spectral analysis. Evoked power in the MEG / EEG signal is estimated by averaging over trials and subsequently entering this average into a time-frequency analysis. To estimate induced power (and what will be used here in this thesis), a time-frequency decomposition is applied on the single-trial level and the resulting power is then averaged over trials. Power originating from background noise and evoked oscillations are subtracted from the total power to uncover the remaining induced power. As David and colleagues describe in their 2006 paper on mechanisms of evoked and induced responses in the MEG/EEG (Neuroimage 31, p.1580):

*"In short, evoked responses can be characterized as the power of the average; while induced responses are the average power that cannot be explained by the power of the average."*

Brain oscillations that are evoked or induced by a cognitive or sensory event are characterized according to the 'natural frequencies' of the brain (delta: 0.5– 3.5Hz, theta: 4-7Hz , alpha: 8-12Hz, beta: 14-30Hz, gamma: > 30Hz).

It is well known that with eyes closed, a dominant alpha rhythm (around 8-12Hz) can be observed from standard EEG recording over parietal-occipital electrode sites, representing a neurophysiological correlate of the resting state (the 'default-mode network' (Raichle et al., 2001)). There is an inverse relationship between alpha and theta oscillations: While theta *synchronizes* with increasing task demand, alpha *desynchronizes*. Consider the following test scenario: When comparing EEG power in a test condition to a resting condition, alpha power typically decreases (desynchronizes) while theta power increases (synchronizes) (Klimesch, 1999; n.b.: the same holds for

beta (desynchronizes) and gamma (synchronizes)). Hence, for both alpha and beta band activity, the amplitude of these oscillations is inversely related to active processing: amplitude reductions correlate with active processing, while increases in these frequency bands denote cortical idling and/or inhibition.

### *Delta oscillations (0.5-4Hz)*

Slow delta oscillations are present during normal, synchronized sleep and are generated by neo-cortical and thalamo-cortical networks, as has been demonstrated by animal studies in cat and rabbit (Petsche et al. 1984; see also Sauseng & Klimesch, 2008). In humans, delta oscillations are assumed to be important for large-scale cortical integration (Bruns and Eckhorn, 2004), and for syntactic as well as attentional language processes (Devrim et al., 1999; Schürmann et al., 2001; Roehm at al., 2004, Schlesewsky, 2001). Furthermore, oddball experiments have shown that delta oscillations are sensitive to signal detection and decision making (e.g. Basar-Eroglu et al., 1992; Basar, 1999; Schürmann et al., 2001).

### *Theta oscillations (4-7Hz)*

Theta oscillations were first described in the rabbit hippocampus due to arousal during sensory stimulation, and have also been studied extensively in rats. In humans, theta oscillations have been shown to correlate with memory load (e.g., Jensen and Tesche, 2002), sustained attention, working memory maintenance, episodic encoding/retrieval processes (see Buzsáki, 2004; Kahana, 2006; Klimesch et al., 1994; Klimesch, 1996; Klimesch et al., 1996; Klimesch, 1999; Klimesch et al., 2001, 2005, 2007a, 2008), stimulus type (Hwang et al, 2005), recognition of previously encountered stimuli (Klimesch et al., 2000; Klimesch et al, 2006), and response-related error processing (Luu et al, 2004). The latter is indicated by a frontal-midline scalp

topography, which has also been shown to correlate with decision-making (Jacobs et al., 2006).

### *Alpha oscillations (8-12Hz)*

Alpha oscillations represent the most prevalent oscillations in the brain and have been generally implied as indicator of the state of awareness in individuals. Following Berger's discovery in 1929, Adrian and Matthews (1934) showed that alpha oscillations vary as a function of the level of attention a subject pays to their visual environment. Based on this, alpha oscillations were long seen as idling process in the visual system, implying that the amplitude of alpha oscillations indicates the level of arousal or focus. Depending on the scalp topography of the effect, activity in the alpha frequency band has been implied to be linked to sensory input or motor output (Bastiaansen et al., 2005; Bastiaansen & Brunia, 2001; Fries, 2005). More recently, this view has been changed towards an interpretation of alpha as a reflection of top-down processes of attentional control (e.g. Thut et al., 2006), or as an inhibitory mechanism in the brain (e.g. Klimesch et al., 2007; Jensen and Mazaheri, 2010). More precisely, though alpha band activity typically decreases with task demands, recent studies have shown that this picture is not as clear cut as it was originally claimed to be: For instance, Jensen et al (2002) and Tuladhar et al. (2008) have observed alpha band power *increases* with memory load over occipito-parietal areas. In addition to this, it has been shown that alpha power also increases in the hemisphere ipsilateral to the attended visual hemifield (Thut et al., 2006; Wyart and Tallon-Baudry et al., 2008). Based on this it has been argued that alpha band synchronization might play a role in actively disengaging cortical areas that are not required in the specific task at hand and therefore enabling functional inhibition (Klimesch et al., 2007; Cooper et al., 2003; Meeuwissen et al., 2011). Inhibitory alpha effects have not only been found over visual posterior brain areas, but also in the

auditory cortex (Krause et al., 1996; Van Dijk et al., 2010) and somatosensory cortex (Haegens et al., 2010).

### Beta oscillations (14-30Hz)

Induced beta oscillations have largely been evidenced in the motor cortex due to movement preparation and movement execution (Kaiser et al., 2001; Pfurtscheller and Neuper, 1997).  In addition to this, action execution, action observation and motor imagery are associated with a power decrease in the beta-frequency range over central and parietal motor areas (Caetano et al., 2007; de Lange et al., 2008; Koelewijn et al., 2008; van Elk et al., 2008b).

Furthermore, oscillatory activity in the beta band is assumed to reflect active inhibition of ongoing processes involved in motor tasks (Pfurtscheller, 1992; Pfurtscheller and Lopes da Silva, 1999; Salmelin and Hari, 1994).

### Gamma oscillations (> 30Hz)

Besides his discovery that alpha oscillations decrease with increasing cognitive demands, Berger (1929) also observed that high frequency oscillations *increase* at the same time. In 1942, the phenomenon of fast neuronal oscillations (30-100Hz) was first reported in animals (Adrian, 1942) and roughly twenty years later in humans (Chatrian et al. 1960). However, investigations in high frequency oscillations only started blooming in the late nineteen-eighties when gamma oscillations were described to correlate with perceptual binding (Gray et al., 1989), attention (Tiitinen et al., 1993), arousal (Strüber et al., 2000), object recognition (Basar et al., 2000; Keil et al., 1999), and language perception (Pulvermüller et al., 1995; Eulitz et al, 1996). Based on results from human EEG (e.g. von Stein et al., 2000; Tallon-Baudry et al., 1996, 1998) and animal studies (e.g. Fries et al., 2001; Friedman-Hill et al., 2000), gamma oscillations have been proven to be involved in perception. There is considerable evidence that gamma power increases

reflect a more general function of feature binding (Rodriguez et al, 1999; Tallon-Baudry & Bertrand, 1999), as it appears to be sensitive to higher-order percepts in a variety of sensory modalities. In addition to this, there is also growing evidence that increases in gamma oscillations are an electrophysiological marker of working memory load (Tallon-Baudry et al., 1999; Howard et al. (2003)).

## 2.3.2 Language comprehension and oscillatory effects

Up to now, the majority of neurophysiological sentence processing studies have concentrated on ERPs to analyse the ongoing EEG / MEG signal. Among the few investigating neuronal oscillations during language processing (e.g., Bastiaansen, van Berkum, & Hagoort, 2002a; Bastiaansen et al., 2002b; Bastiaansen, Van der Linden, ter Keurs, Dijkstra, & Hagoort, 2005; Pulvermüller, Lutzenberger, & Preissl, 1999; Schack, Weiss, & Rappelsberger, 2003; Weiss & Rappelsberger, 1996; Weiss, Müller, King, Kutas, & Rappelsberger, 2001; Weiss, Müller, & Rappelsberger, 2000; see also review by Weiss & Müller, 2003), power and coherence changes in oscillatory neuronal activity in response to time-locked events have been reported in delta (<4 Hz), theta (4-7 Hz), alpha (8-12 Hz), lower beta (13-18 Hz), and in gamma (above 30 Hz). It is quite remarkable that many language tasks appear to elicit power and coherence changes particularly in the lower frequency bands, with many studies reporting informative changes in the theta and alpha frequency range. Bastiaansen et al. (2002b) for instance investigated two different agreement manipulations in Dutch compared to a correct control (5a), i.e. gender agreement (5a) and number agreement violations (5b) – both of which have shown to evoke a P600 component in the EEG (van Berkum et al., 2000):

> (5a) Ik zag een donkere wolk ann de horizon.
> (5b) Ik zag een donker *wolk* aan de horizon.
> I saw a dark$_{NEUT}$ cloud$_{NON-NEUT}$ on the horizon.

(5c) Ik zag enkele donkere *wolk* aan de horizon.

I saw several dark cloud on the horizon.

Although they found for both violation types increases in the theta frequency band (4-7Hz) in a latency range of 300-500ms after stimulus onset, the local maximum showed different distributions on the scalp surface: *gender agreement* elicited an increase in theta power over *right* anterior electrode site, whereas *number agreement* elicited a theta power increase over *left* anterior electrodes. While the ERP analysis revealed a quantitative difference between number and gender agreement (due to the fact that the P600 effect with an identical scalp distribution was larger for number than for gender agreement violations), the hemispheric difference of the anterior theta effect uncovered a qualitative difference between the two experimental manipulations. Similarly, there was a difference between the latency of the ERP effect (500-800ms) compared to the latency of the theta power increase (300-500ms).

Hald et al. (2006) compared semantic violations (6b) to a semantically coherent control (6a) and reported similar effects to the ones reported by Bastiaansen and colleagues:

(6a) De Nederlandse treinen zijn *geel* en blauw.

The Dutch trains are *yellow* and blue.

(6b) De Nederlandse treinen zijn *zuur* en blauw.

The Dutch trains are *sour* and blue.

Semantic incongruity has been shown to induce alpha band activity that temporarily precedes its corresponding N400 component (Allefeld, Frisch & Schlesewsky, 2005). Moreover, Roehm et al. (2004) demonstrated that while N400 effects were indistinguishable between semantically incongruent and outright ungrammatical conditions, the former gave rise to increased activity in the higher

theta band (6-8 Hz), while ungrammatical stimuli led to an increase in the lower theta band (3-5 Hz). Furthermore, Hagoort et al. (2004) suggested that theta band activity is a likely generator of the N400 component. The authors also reported a gamma-band component that seems to have no direct reflection in the N400. More recently, Bastiaansen, Mazaheri and Jensen (2011, p. 22) have suggested that oscillatory effects during language processing appear to correspond with the cognitive architecture of language comprehension (Hagoort, 2004), i.e. effects related to memory retrieval operations during language comprehension, and effects related to the integration or unification of linguistic information. Many studies have illustrated power changes in theta (4–7Hz), alpha (8–12Hz), and beta (>13–30Hz) not only during the processing of sentences containing syntactic and semantic violations (Bastiaansen et al. 2002b; Hald 2006), and the processing of open-class words vs. closed-class words within a sentence context (Bastiaansen et al., 2005), but also for correct sentences (Bastiaansen 2002a). Common to these studies is that particularly power changes in the theta frequency range appear to be sensitive to different linguistic manipulations, implying a functional role of the theta band for language processing. Theta power increases were observed over three distinct brain areas: bilaterally over the temporal cortex, over fronto-central areas, and over left occipital areas. The (left) temporal theta increase has been likewise linked to lexico-semantic retrieval (Bastiaansen et al., 2005), and to increased verbal working memory load (Bastiaansen et al., 2002a). The left occipital theta response has been associated with visual word form encoding. As fronto-central theta increases with working memory (WM) load (Bastiaansen et al., 2002a, Weiss et al, 2001), after syntactic and semantic violations (Bastiaansen, 2002b, Hald, 2006), and after both open-class and closed-class words (Bastiaansen et al., 2005), a functional dissociation is more complex. The syntactic violation effect in Batiaansen (2002b) over frontal electrode sites may be due to a larger verbal working memory load because the sentence needs to be re-analysed. In line with this, Hald et al.

(2006) suggested that their frontal theta effect elicited by semantic violations reflects an increase in verbal WM because the reader has to evaluate online whether the current word can be successfully integrated into the sentence context. Interestingly, there is a second interpretation for the frontal-midline theta increase (Bastiaansen, 2002a; Hald, 2006): Both syntactic and semantic violations signal an error compared to a correct control sentence, implying that this effect can also be explained in terms of general error monitoring mechanisms. The authors suggested that the observed frontal theta increases are linked to the error-related negativity (Falkenstein, Hohnsbein, Hoormann, & Blanke, 1991; Gehring, Goss, Coles, Meyer, & Donchin, 1993). The error-related negativity (ERN) represents an ERP component that is elicited when subjects make erroneous responses. Studies investigating the ERN by means of time-frequency analysis have found that the ERN is largely generated by frontal-midline theta oscillation, which are phase-locked with respect to the erroneous response (Luu & Tucker, 2001). In view that the different types of violations show hemispheric differences (semantic violations: midline; syntactic violations (gender agreement): right lateral; syntactic violations (number agreement): left lateral), they may be interpreted as domain-specific processes that impose on general error detection mechanisms.

As mentioned in chapter 2.2.1, alpha power *increases* (8-14Hz) have been shown to play a vital role in working memory involving non-linguistic tasks (e.g. Jensen et al., 2002). Interestingly, this also seems to extend to the sentence processing domain: In a recent study, Meyer, Obleser, and Friederici (2012) recorded EEG while participants listened to German sentences employing either a short or long distance between a subject or object and the sentence-final verb. Time-frequency analyses revealed a sustained oscillatory power increase at 10 Hz during verbal working memory storage prior to the sentence-final verb for the long-distance sentences as compared to the short-distance sentences. The alpha power synchronization effect was

followed by a transient power increase in the beta band (13–20 Hz). Source analysis localized the maximum activity for the alpha power increase bilaterally in the occipital cortex and in the left parietal cortex.

The neural basis and functional interpretation of activity in the higher frequency bands in relation to linguistic paradigms remains still unclear, particularly with regard to the beta-band rhythm. This may be attributable to the largely divergent evidence in the language domain (see Bastiaansen et al., 2005). Luo et al. (2010) suggested that the variety in the interpretations of the beta-band power is due to the fact that these studies have focused on different frequency ranges within the beta band. For instance, Weiss and Rappelsberger (1996) observed differences between 13–18 Hz when comparing concrete to abstract nouns. As mentioned above, Bastiaansen et al. (2005) reported a power decrease in 16–21 Hz for both open class and closed class words and proposed that the power decrease reflects sensory processing of the visual input. By contrast, Davidson and Indefrey (2007) reported a power decrease between 13–30 Hz for phrase structure violation and suggested that this reflects increased participation of cortical areas in grammatical processing after a violation is encountered. More recently, Luo et al (2010) investigated how the processing of prosodic constraints can be distinguished from the processing of semantic constraints by measuring changes in event-related electroencephalogram (EEG) power. They visually presented Chinese sentences containing verb–noun combinations that were semantically congruent or incongruent and that had either a normal or abnormal rhythmic pattern. They observed a larger power decrease in 16–20 Hz in response to semantic violations in a very early time window (0–200ms post onset) as well as in a later time window (400-657ms), while an abnormal rhythmic pattern led to a power decrease in the upper beta-band (20-24Hz) for the late time window only. They concluded that it is not very likely that the beta band activity reflects simply sensory processing, but may be more likely to reflect linguistic functions in language processing. Luo and colleagues concluded that

the power decrease in the early and later time windows in the 16–20 Hz frequency band for semantic violations could reflect continuous processes related to lexico-semantic integration and reanalysis, whereas the power decrease in the later time window in the upper beta frequency band for abnormal rhythmic patterns indicates a reanalysis/repair process of prosodic structure after coming across the abnormal rhythmic pattern.

Contrary to that, there have also been reports of increases of beta band power in response to linguistic manipulations: Weiss et al. (2005) for instance investigated EEG coherence while participants read so-called subject-relative clauses (SR) compared to EEG coherence during object-relative (OR) sentences. Generally speaking, SR sentences are very frequent in everyday language and syntactically uncomplicated, while OR sentences are less frequent and more challenging which in turn leads to a larger load on verbal WM. Weiss et al. found that increased theta and gamma coherences were associated with the higher WM load. In addition to this, they reported that the lower beta band (13-18Hz) was sensitive to effects of syntactic complexity, which was reflected in an increase of coherence. In line with Hagoort MUC model, Bastiaansen and Hagoort (2006; see also Bastiaansen et al. 2010) have suggested that syntactic unification operations, typically induce high-frequency neuronal synchronization in the beta frequency (12–30 Hz) as reflected by increases in beta band power.

In terms of spoken sentence comprehension, Hickock and Poeppel (2007) have suggested that the left and right hemisphere operate at different frequencies, implying a lateralization of these effects: They propose that the left hemisphere predominantly operates in the gamma frequency range while the right hemisphere operates in the theta frequency range. In conclusion, it appears extremely promising and valuable to go beyond classical ERP analysis and examine induced neural activity in the time-

frequency domain. In the context of error detection and repair due to conflicting input, this represents a novel approach to uncovering the underlying neural processes.

## 2.4 Domain-specific vs. Domain-general cognition

### 2.4.1 Automatic vs. controlled processing

Domain specificity is believed to be one of the most important features of psychological adaptations. More accurately, domain specific adaptations develop in order to solve problems in a particular domain, and are therefore considered to be less well suited to solve problems in other domains. Many have argued that language is 'special' and should hence rely on specialised adaptions solely devoted to processing language.

Even so, recent results emphasize that domain-general executive resources such as working memory, control mechanisms, and planning resources substantially contribute to sentence comprehension (Friederici, 2002; Novick et al., 2005; MacDonald and Christiansen, 2002). This theory challenges the general idea that human cognition can be broken down into functionally independent processes, which are assumed to operate over distinct domains of information. During the last decade, researchers in cognitive science have addressed the question whether human cognition relies on domain-specific, encapsulated information systems only or whether it is driven by domain-general cognitive mechanisms. Historically, the idea of a domain-specific organization of the mind is closely related to the traditional idea of modularity (Chomsky, 1957; 1965; 1988; Fodor, 1975, 1983, 2000; Carruthers, 2006). Although many cognitive scientists have a much looser sense of modularity nowadays, the "fodorian" definition of modularity still represents the centerpiece of many neuronal models. According to Fodor (*The Language of Thought (1975)* and *The Modularity of Mind (1983)),* modules that engage in domain-specific processing are among other things:

(A) Informationally encapsulated – other psychological systems in the brain can neither influence nor access the particular machinery of a module;

(B) Domain-specific: modules are specialized to compute only a constrained class of input in a bottom-up manner;

(C) Fast – because they are encapsulated, modules can perform their functions very quickly;

(D) Hard-wired and of a fixed neural architecture;

(E) Mandatory and automatic – whenever relevant information becomes available, the module's algorithms are activated;

Evidently, modularity relates to the degree to which cognitive domains can be considered separable, and in particular whether they operate independently of one another. Still, what exactly defines a module varies immensely across and theoretical approaches and fields of research.

Nevertheless, Fodor differentiates domain-specific modules from the "central systems", which are by definition non-modular and informationally unecapsulated. In a personal e-mail correspondence Fodor clarified (August 2006):

> *"As Kant pointed out, something in your head has to integrate all this stuff, and it's non-modular by definition."*

According to Fodor, the central system is a domain-general entity to which the modules from any cognitive domain feed into, i.e. information originating from different sensory modalities is integrated here. Another key aspect of the central system is human reasoning, which is important for instance during analytical or metaphorical thinking, decision making, trouble-shooting, and inferential processing (e.g. Schneider, 2007).

More recently, Dehaene, Changeux and Naccache have suggested their "Global Workspace Theory", which was first proposed by Baar (1982; 1989) and is based on the hypothesis of a "conscious *neuronal* workspace" (Dehaene & Changeux, 2000; Dehaene, Kerszberg, & Changeux, 1998; Dehaene & Naccache, 2001; Dehaene, Sergent, & Changeux, 2003). This particular model of consciousness builds upon Fodor's distinction between modular capacities and a separate central system that is able to share information across the domain-specific modules. More specifically, Dehaene and colleagues stress the importance of distributed neurons with long-distance connections, which are particularly concentrated in prefrontal, anterior cingulate, and parietal regions. These neurons allow to link multiple specialized modules and - at the same time - enable the spontaneous broadcasting of information to multiple neural areas. Importantly, these areas are not activated during automatized tasks, but appear suddenly when an automatized tasks triggers conscious control. For instance, many studies have illustrated that cingulate and prefrontal areas are activated immediately after errors and whenever conflicts must be resolved (e.g. Carter et al., 1998; Dehaene, Posner & Tucker, 1994).

With automatisation however, activation usually decreases in dlPFC (dorsolateral prefrontal cortex) and ACC (anterior cingulate cortex). Therefore, automatic processing should lead to activation in specialized processors throughout the cortex, but does not require the coordination of global workspace neurons through large-scale networks.

### 2.4.2 Domain-general control in sentence comprehension

As described above, some theories of consciousness are based on the idea that specific cognitive mechanisms are strongly tied to consciousness. Among those mechanisms is the concept of cognitive or executive control. Functions typically associated with cognitive control are for instance error detection, conflict monitoring and conflict resolution, task switching, and response inhibition. It is widely believed (and has been evidenced many times) that these functions rely on the prefrontal cortex (PFC). Interestingly, many also assume that this brain region is responsible for generating awareness (Dehaene and Changeaux, 2011; Lau and Rosenthal, 2011, van Gaal et.al, 2012).

Clearly, successfully resolving conflicting or interfering information is essential to everyday life as it is required almost in any situation that is outside our normal routine. The ability to flexibly adapt behaviour in face of complex or incompatible information critically depends on higher-order cognitive functions that regulate and guide lower-order ones (Miller and Cohen, 2001). Cognitive control has been the focus of growing research in cognitive psychology, mostly involving attentional, perceptual, or motor tasks (Botvinik, 2001; Posner & Snyder, 1975; Fan et al., 2007). Despite substantial progress to determine the neuronal underpinnings of cognitive control for low-level cognitive functions such as perception or motor control, research has largely failed to consider the role of cognitive control in language comprehension. This is surprising, as the ability to express thoughts, to communicate and to rapidly understand who did what to whom is ultimately a human trait, and certainly a crucial feature of human cognition. In order to determine how we understand language, it is important to establish whether our behaviour is guided by general cognitive mechanisms or by highly specific subroutines.

Language comprehension involves various cognitive mechanisms, including input-driven bottom-up syntactic parsing and top-down prediction-driven heuristics, which may be partly modulated by domain-general processes such as attention, working memory, and cognitive control (Herten, Chwilla, & Kolk, 2006). Consequently, cognitive control mechanisms are also thought to be important in situations where linguistic conflicts arise and the reader or listener has to select between competing sentential interpretations as for instance during the processing of locally ambiguous garden-path sentences, or when the selection between simultaneously activated lexical items becomes necessary.

In recent years, it has been argued that the cognitive control mechanisms recruited in sentence processing strongly overlap with those in attention and perception (Ye & Zhou, 2009; Herten, Chwilla, & Kolk, 2006; January et al, 2008; Novick et al., 2005). More specifically, executive functions that resolve competing representations in memory and motor tasks may be similarly activated during successful language comprehension (Novick et al, 2005).

This proposal clashes with the traditional modular view that sentence comprehension is a highly specialized cognitive task, which engages dedicated domain-specific modules (Chomsky, 1975; Fodor, 1983). Adapting this modular view, it has been suggested that linguistic conflicts are exclusively resolved within domain-specific, strongly *localized*, linguistic networks and are not assisted by domain-general control mechanisms (Kuperberg, 2007).

Linguistically specific processing demands are assumed to selectively engage left hemisphere systems, particularly involving the middle temporal gyrus (BA 21), the inferior frontal gyrus (Broca's area, BA 44), the angular gyrus (BA 39), and the supramarginal gyrus (BA 40). As Hagoort (2005) pointed out, the left temporal cortex in particular is believed to be important for storage and retrieval of linguistic

information, including syntactic properties such as grammatical gender, word class, and phonological features of words, and retrieving this information should happen in a much automatised manner.

There is no doubt that language processing relies on highly specific processors or modules. However, there may be situations where these specialized subroutine are not sufficient and the brain recruits flexible processors outside the language system. In line with these ideas we suggest that if linguistic conflict cannot be resolved within the linguistic sub-system itself, the resolution process should rely on connectivity within large-scale neuronal networks, mostly involving domain-general prefrontal, anterior cingulate, and parietal areas. As described above, the neural mechanisms involved in *controlled processing* typically engage prefrontal regions, particularly the dorsolateral prefrontal cortex (DLPFC) [Brodmann area (BA) 9 and BA 46], the anterior cingulate cortex (ACC) [BA 24 and BA 32], as well pre-motor areas during working memory maintenance (BA 8, BA 6). It is important to note that these brain areas thoroughly correspond to those implied in the "conscious *neuronal* workspace" theory. Moreover, they are considered to represent a *domain-general network*, which is assumed to generalize across different types of conflict and domains (Freitas et al., 2007; Stürmer et al. 2005, Zhaki et al., 2010). Nevertheless, several studies have reported domain-specific effects to conflict-induced control while others have suggested that domain-specific as well as domain-general networks mediate cognitive control (Fernandez-Duque et al., 2008; Kunde et al., 2007). Recent findings suggest that theta band synchronization in particular is sensitive to the recruitment of domain-general executive control in interference situations (von Stein, 2000; Sarntheim et al., 1998). In particular, there is EEG evidence that the medial frontal cortex uses theta oscillations to coordinate local and long-range neural networks in situations where controlled processing comes into play (Cohen, 2011). Other studies have suggested that cognitive control in sentence processing gives rise to a P600 effect (Novick et al.,

2005), which is occasionally preceded by an N400 effect (Kuperberg et al, 2006a). This is in agreement with early EEG studies claiming that late ERP components are associated with controlled processes, while early components such as the ELAN reflect automatic processing (e.g. Hahne & Friederici, 1999).

## 2.5 Incrementality and predictive processing

One aspect that might substantially contribute to linguistic conflict resolution strategies is the matter of predictive processing and prediction error. It is likely that *anticipation* or *prediction* is a universal principle of higher cognition and necessary for everyday survival by facilitating any kind of human behaviour (Bar 2007). Predictions are typically made on the basis of expectations about which event is the most likely to occur and, depending on the specific scenario, are made with more or less certainty. Overall, predictions can result both in benefits and costs, depending on whether predictions are confirmed or disconfirmed. Recently, research has seen growing interest in the role of predictive processing in language processing (Federmeier, 2007; Pickering & Garrod, 2009, Dikker & Pylkkänen, 2011).

Many psycholinguistic studies have shown that sentence comprehension is highly incremental: driven by the contextual cues given in prior context, people constantly anticipate how the sentence unfolds over time (Altmann & Kamide, 1999; DeLong, Urbach, & Kutas, 2005; Van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005). One of the most prominent examples of predictive processing in sentence processing has been evidenced in response to articles or adjectives according to whether they matched or mismatched the gender of an expected upcoming noun (Van Berkum, Brown, Zwitserlood, Kooijman, &

Hagoort, 2005; Wicha, Bates, Moreno, & Kutas, 2003; Wicha, Moreno, & Kutas, 2003, 2004).

In recent years, models of expectation-based syntactic processing have been developed (e.g. Hale, 2003, 2006; Levy, 2008) that suggest that the processing difficulty associated with a word in a sentence strongly depends on its predictability given in the sentence so far.

In addition to this, predictions notably vary in different contexts, suggesting that various factors such as e.g. the relationship between certain events, the context or frequency of their appearance, and many more may impact the quality and strength of predictions (Bubic et al., 2010). More precisely, in certain circumstances predictions are made in a very unspecific manner about an incoming stimulus, e.g. they may be limited to the sensory modality or the orientation of the stimulus, while in others contextual restrictions can render them very specific.

In line with these ideas, we propose that context-based forward predictions determine whether conflicts arising from inconsistent linguistic information are resolved, or attempted to be resolved, in an automatic fashion by activating domain-specific, localized linguistic subsystems or if cognitively general systems involving large-scale neural networks with activation in prefrontal regions assist in doing so.

In other words, if linguistic information strongly cues future linguistic information, then linguistic processing and conflict resolution are expected to be tied to strongly localized linguistic systems. However, if future information is uncertain or even unforeseeable, then the processing of conflicting information is expected to engage cognitively general systems specialized in flexible conflict resolution and top-down cognitive control.

Although many studies investigating electrophysiological markers of predictive processing in the ERP profile have reported effects in the MMN time

range (100–200ms after the deviant stimulus), more recent research has identified even earlier manifestations of predictive processing. For instance, electrophysiological markers for predictive processing in response to both 'matching' and ''mismatching' stimuli have been found as early as 40–50ms after stimulus onset (e.g. Grimm, 2011; see Bendixen et al., 2012 for review).

Other ERP components that were reported as marker of failed predictions are the early right anterior negativity (ERAN), which is elicited by violations of musical expectations (e.g. Koelsch et al., 2001), the early left anterior negativity (ELAN) in response to syntactic violations (e.g., Hahne and Friederici, 1999; Dikker, 2009, and the error-related negativity (ERN, e.g. Falkenstein et al., 1991). The latter represents a component, which is elicited when an own response is detected to be erroneous. Some have argued that later ERP components such as the N400 and the P600 are also indicative of predictive processing, but most researchers agree that the speed with which the relevant effects are observed is crucial for predictive processing (e.g. Lau et al. (2006), Dikker et al. 2009).

## 2.6 The Experimental Test Cases

This thesis focuses on the investigation of the following three questions:

(1) Is it possible to determine correlates of automatic and controlled processing during linguistic conflict resolution in the frequency profile and the time-domain of the EEG / MEG signal?

(2) Do large-scale networks associated with executive functions assist linguistic conflict resolution?

(3) Do areas in the prefrontal cortex contribute to linguistic conflict resolution and how does predictive processing influence these processes?

To study the electrophysiological correlates of linguistic conflicts in sentence processing, we used structures that are amongst the most well-studied in psycholinguistic research. More precisely, these test cases have been shown to behaviourally lead to longer reading times and to reliably elicit distinct ERP components: sentences that are locally ambiguous but that allow successful reanalysis (EEG Exp.1, syntactic garden-path processing), the resolution of agreement violations triggered by conflicting pronoun information (EEG Exp. 2: anaphora sentences, EEG Exp.3: cataphora sentences), and cognitive load due to syntactic complexity in syntactic garden-path sentences (MEG Experiment 4). The following sections gives a brief description of the particular sentences involved, but these will be explained in more detail in the introduction of the relevant experiments. The analysis focuses on data analysis in the amplitude-time domain of the EEG / MEG signal, event-related desynchronization and synchronization in the time-frequency domain, and is complemented by source localization of the observed effects.

### 2.6.1 Main verb vs. reduced relative ambiguities

One of the primary goals of psycholinguistic research has always been to provide a systematic account of how people interpret structurally ambiguous sentences. Researchers have long been interested in how we are able to recover from temporary ambiguities sentences and in which situations we are unable to do so. Although conflicts induced by temporary ambiguities are very common, certain sentences can lead the reader or listener to commit without reservations to a wrong interpretation - only to be forced to abandon the initially pursued interpretation in favour of a less preferred one at a later stage.

Two experiments in this thesis (Experiment 1 (EEG, auditory modality) and Experiment 4 (MEG, visual modality) focus on a kind of temporary syntactic

ambiguity, which has first been showcased by Bever's (1970) well-known "garden-path" sentence *"The horse raced past the barn fell"*. In this sentence, the verb *"raced"* is morphologically ambiguous because it can be analysed in two ways: either as a simple past tense main verb, or as a past participle. Most people find the sentence extremely difficult to process at the verb *"fell"*, suggesting an almost irresistible preference to analyse *"raced"* as a main verb to the noun phrase "the horse": This decision leads to the so-called "garden path effect." As has been proposed by Frazier (1978), garden-path effects indicate that alternative structural continuations that arise at the point of ambiguity are not given equal priority. Rather, there is one privileged continuation that the parser prefers to pursue while the other possibilities are abandoned.

For example, when participants read the string "The engineer examined by . . ." structural information tied to the lexical entry for *examined* may initially strongly favour a subject–verb–object structure over possible alternative structures. To my knowledge, only three electrophysiological studies have used this particular type of structural ambiguity, two of them investigating syntactic priming (Osterhout & Holcomb, 1994; Ledoux et al., 2007; Tooley et al. 2009), but none have looked into the oscillatory profile as of yet.

Osterhout and Holcomb (1992) were the first ones to observe reliable P600 effects in response to this sentence type. Similarly, Ledoux et al. (2007) and Tooley et al. (2009) observed a modulation of the P600 effect at the earliest point at which the preferred syntactic analysis has to be abandoned (the word "by"), but only when the prime and target sentences contained the same past participle.

Recently, it has been suggested that syntactically (temporarily) ambiguous garden-path sentences recruit executive functions to suppress the preferred interpretation, which is no longer supported by new inputs (Novick et al., 2005). For

instance, Thompson-Schill and colleagues (Novick et al., 2005; Thompson-Schill et al., 2005) suggested that the left inferior frontal gyrus may be responsible for resolving conflict when representational conflicts arise, while others suggest that this is reflected in activation in large-scale networks, including frontal, parietal and sub-cortical structures (e.g. Ye & Zhou, 2009).

### 2.6.2 Anaphoric pronoun resolution

Another requirement for successful language comprehension that is performed very frequently in everyday speech entails that the reader or listener rapidly interprets referential forms such as *she*, *him* or *herself*. Pronouns and reflexives belong to the most frequently encountered words in our language, and linking referential forms to the entity they refer to is typically achieved through the use of anaphora. The process by which an antecedent is assigned to an anaphor is called anaphor resolution. For instance, in "The man is happy, because he won the lottery" the pronoun "he" is an anaphor and refers back to the antecedent noun "man". Thus, in order to understand an utterance containing a pronoun or reflexive, the reader or listener needs to correctly assign it to a suitable antecedent. Because of their vital role during language comprehension, the mechanisms underlying pronoun resolution have been thoroughly studied in cognitive science using various behavioural methods (e.g. Garnham, 2001; Sanford and Garrod, 1989; Trueswell and Tanenhaus, 2005). Many of the studies employing anaphoric constructions did not specifically investigate anaphoric processing: rather, anaphoric constructions were used to investigate other questions, primarily questions about the nature of the underlying parsing mechanisms.

Anaphora resolution is an interesting test bed to study contributions of top-down mechanisms as opposed to bottom-up automatic processes because it requires integration between different levels of representations. More specifically, anaphor

resolution is not determined by a single constraint but rather is the result of the interaction of multiple constraints, e.g. grammatical constraints (Chomsky, 1981) as well as context and discourse constraints (e.g. Garnham, 2001).

Specifically, experiment 2 and 3 investigate how predictive processing constraints impact the conflict resolution mechanisms when the parser is confronted with conflicting pronouns. In order to do this, we employ a gender-mismatch paradigm in anaphora and cataphora sentences. Cataphora are often referred to as 'backwards anaphora', as the order of pronoun and co-referring noun is reversed. Take for instance the above mentioned example: The cataphoric equivalent would be "Because he won the lottery, the man was happy." Studies on cataphora using self-paced reading and eye-tracking (Kazanina et al, 2007; Kreiner et. al., 2008) have suggested that conflicts resulting from mismatches between the gender of the pronoun and the gender of the co-referring noun are resolved by using a predictive processing strategy. In anaphora, gender mismatches typically elicit P600 components. There have not been any electrophysiological studies using cataphora sentences yet. However, if predictive processing impacts conflict resolution in cataphora, this may be reflected in early components in the EEG signal.

# 3. EEG Experiment 1: Brain potentials elicited by syntactic garden-path sentences in spoken sentence processing
(Ethics project number: FIMS00574)

## 3.1 Sentence comprehension and Repair / Reanalysis

During the past decades psycholinguistic research has tried to dis-entangle the cognitive processes underlying language comprehension. To fully understand a sentence, the reader or listeners needs to combine single words in order to activate the appropriate syntactic structure and to arrive at a meaningful interpretation (Chomsky, 1965; Chomsky, 1981; Jackendoff, 2007). Broadly speaking, sentence comprehension requires making use of two sources of information, namely *syntax* and *semantics*. Syntactic processing involves - in early stages - determining the relationship between individual words based on lexical information and word order, while later processes deal with representing syntactic information in working memory and repairing or reanalysing misparsed constituents (Caplan & Waters, 1999; Kaan & Swaab, 2003, Humphries et al, 2006). Semantic processing on the other hand implies identifying the sentences' overall meaning by piecing together the semantic representations of its individual words. Alas, *when* syntactic and semantic information are being *accessed* and how they *interplay*, still remains controversial. Nonetheless, previous research has identified two alternative views of psycholinguistic comprehension models: The *serial* or *syntax-first model* proposes that syntax is processed independently and prior to semantics (Frazier, 1987; Frazier, L. & Fodor, J. D., 1978), whereas *interactive* and *constraint-based models* argue that both sources of information communicate at any stage of the comprehension process (Marslen-Wilson, W.D. & Tyler, L.K., 1980; McClelland, J.L. et al., 1989). Regardless at *which* point syntax and semantics interact, both comprehension models agree that the listener or reader needs to make use of syntactic as well as semantic information to understand an utterance. For most spoken and written sentences this process is effortless and straightforward and does

not cause any processing difficulty. Yet, studies in sentence processing have shown that people find it difficult to comprehend temporarily ambiguous sentences such as:

(7) *"The nurse examined by the doctor was not on duty."*

This is because they initially interpret *"The nurse"* as the subject of the verb *"examined"* – an interpretation that is not supported by the inclusion of a by-phrase. They are being led up the *"garden-path"* and understand *"The nurse examined"* as the beginning of a main clause (as in *"The nurse examined the child"*). Coming across the prepositional phrase "*by the doctor*", it soon becomes clear that the initial interpretation is wrong. As a consequence, *"examined by the doctor"* needs to be reanalysed as a reduced relative-clause modifier of the first noun phrase (NP) "*the nurse*". Attempting to revise the sentence towards an unpreferred syntactic analysis, the reader/listener typically faces processing difficulty. This process has been termed the so-called *"garden-path effect"* (Frazier, 1987) and has been thoroughly evidenced in longer reading times in eye-tracking and self-paced reading (e.g. Clifton et al., 2003; Ferreira & Clifton, 1986; Trueswell et al., 1994).

Attempting to shed light on the garden-path phenomenon, several models of reanalysis were developed that tried to explain what happens when the reader or listener needs to abandon a preferred analysis in favour of a normally unpreferred interpretation (Fodor & Inoue, 1994 & 2000; Gorrell, 1995; Lewis, 1998; Sturt & Crocker, 1996). As claimed by Fodor & Inoue's diagnosis model (1994), resolving locally ambiguous garden-paths involves two distinct processes: *error detection* (i.e. identifying the error that occurred during initial parsing) and *syntactic repair* (i.e. revising the error to arrive at the correct interpretation). The error is represented by the input that cannot be integrated in the current representation of the sentence. Speaking in terms of the above example, the processing difficulty emerges as soon as the reader

or listener encounters the disambiguating phrase *"by the doctor"*. If the parser is successful, he or she eliminates the error and obtains the appropriate interpretation.

Numerous eye-tracking studies in which eye movements were recorded during the comprehension of sentences containing structural ambiguities have provided support for Fodor & Inoue's garden-path model. They found that eye fixations were longer and eye regressions were more frequent when readers encountered disambiguating material that was inconsistent with the favoured interpretation (e.g. Frazier & Rayner, 1982; Rayner et al. 1983). It is also important to note that the existence of garden-path effects also provide evidence that the reader or listener processes language *online*, i.e. immediately as it is heard or read.

Although the main clause/relative clause ambiguity for English is a well-studied phenomenon in behavioural psycholinguistic research, relatively little is still known about its neurophysiological signature and origin. Moreover, using Eye-tracking and self-paced reading solely on their own, does not allow to pinpoint the mechanisms involved in error detection and repair during the comprehension of syntactic garden-path sentences.

During the past years, some studies in psycholinguistic research have therefore paid considerable attention on the electrophysiological outcome during the processing of garden-path sentences. Among those approaches is the *neurocognitive model of sentence comprehension* proposed by Friederici (2002; see also chapter 1.1), which has strong parallels to Fodor and Inoue's diagnosis model: It suggests that the stages of reanalysis (*error detection* and *repair*) elicit distinct event-related potentials and are therefore reflected in different electrophysiological components:

The electrophysiological pattern for reanalysis or repair is that of a positive deflection, arising about 600ms post-stimulus onset and with a prevalently centro-parietal distribution (P600) (e.g. Ledoux et al., 2007 and Tooley et al., 2009). This

component is often preceded by a left-anterior negativity (LAN) in the 300–500ms interval (Barber and Carreiras, 2005, De Vincenzi et. al, 2003; Molinaro et al, 2008; Osterhout and Mobley, 1995, Rossi et al, 2005), implying that the LAN activity can be functionally interpreted as instantiating the detection of a morphosyntactic anomaly (Friederici, 2002; Münte et al, 1997).

There have not been any studies investigating the frequency profile during garden-path recovery, therefore we can only speculate about the potential outcome:

Generally, tasks that involve resolving conflicts in interference situations are thought to involve central executive control. Historically, the central executive is hypothesised to be a component of working memory - a system that temporarily stores and manipulates information (Baddeley & Hitch, 1994; 2000). The central executive is assumed to assist attentional control functions, for instance focusing attention under conditions of interference, switching attention between different information sources, and dividing attention during multi-tasking (Baddeley, 1986, 1998; Baddeley & Logie, 1999). These processes are typically assumed to activate a network of prefrontal (dorsolateral prefrontal cortex, dlPFC), anterior cingulate (ACC), and parietal regions.

Given the processes hypothesized to be necessary for the re-interpretation of garden-path sentences (e.g., resolving interference through the processes of error detection and repair), it stands to reason that these mechanisms overlap with those served by the central executive in the prefrontal cortex (see Novick et al., 2005 for a review).

Some studies looking at event-related potentials have provided evidence for a role of the left inferior frontal gyrus (LIFG) during garden-path recovery (January, Truewswell, & Thompson-Schill, 2009; Mason, Just, Keller, & Carpenter, 2003; Novick, Trueswell, & Thompson-Schill, 2010, Novick et al., 2005).

Similarly, studies using perceptual and attentional tasks have shown, that error detection is reflected by an increase of ongoing frontal-midline theta (4-7Hz) activity, while the underlying source of this activity has been traced back to the ACC (Tucker, 2003; Makeig et al., 2002). As garden-path sentences generally impose an increased demand on Working Memory, activation in areas associated with working memory demands such as the inferior frontal gyrus (IFG), the superior frontal gyrus, premotor cortex, and inferior parietal regions is also very likely (Christensen, 2010; Bor, Cumming, Scott, & Owen, 2004; Bor & Owen, 2007; Smith & Jonides, 1999).

## 3.2 Methodology

This ERP study investigated the processes that are present in spoken, syntactically ambiguous English sentences (i.e. reduced-relative clauses) at the point of disambiguation. For the materials we collected approximately 150 verbs that employ a participle / main verb ambiguity, of which the 128 most suitable ones were selected for the final sentence materials. These experimental items consisted of 128 English sentences in two conditions each, as illustrated in Example (8).

Example (8):

**Condition (1)** *The nurse that was examined by the doctor was not on duty*

**Condition (2)** *The nurse examined by the doctor was not on duty.*

Condition (1) served as baseline condition, i.e. a well-formed full relative clause where no processing difficulty was expected. Condition (2) in contrast employed a so-called garden-path sentence, a reduced-relative clause that was expected to exhibit processing difficulties (for full materials see Appendix A.1). Note that the conditions differ just in one respect from one another, namely that in condition (2) the "that was"

is omitted. The experimental sentences were spoken by an experienced female speaker, with normal intonation at a normal speech rate using a Mini Disk recorder sampling at 44 kHz with a 16-bit resolution. Although the experimental items were recorded for both conditions, we were concerned that diverging prosodic features between the two conditions might affect (or even *explain*) the electrophysiological outcome of Experiment 1. Hence, it was desirable to keep prosody, intonation and stress constant between the experimental conditions. Therefore, the critical *"garden-path"- condition* (2) was derived by cutting out *"that was"* and cross-splicing the underlined parts of condition (1) into condition (2) (see Example 8). A speech waveform editing software (Audacity Version 1.2.6a) was used to mark the onset of the critical verb (*"examined"* in Example 8) to determine the *"junction"* where condition (1) was cross-spliced into condition (2).

For condition (2), then, we ended up with naturally recorded sentences as well as artificially derived versions (as explained above). Since only the latter were to be used in the main experiment, we had to make sure that they were not perceived as unnatural.

### 3.3 Pre-test: Acceptability judgement

To evaluate the perceived naturalness, the cross-spliced items where entered into an offline acceptability judgement task, to be compared with their naturally recorded counterparts. This was done to ensure that the items did not sound "unnatural" and might therefore elicit certain ERP components unrelated to the question of interest. For that reason, we asked participants to compare the naturally recorded version of the critical *reduced relative clause* conditions with their cross-spliced versions. Hence, the major goal of this pre-test was to confirm that the manipulated sentences did not significantly differ from their naturally recorded counterparts.

***Participants.*** 20 native speakers of English (11 Females, 9 Males, mean age = 20.1), most of them recruited from the Glasgow University undergraduate subject pool, received course credits for their participation in this experiment. All of the participants had normal or corrected to normal vision, normal hearing, and were naïve with respect to the experiments' purpose.

### 3.3.1 Design & Materials

All 'garden-path' items in two versions each (the naturally recorded one and the cross-spliced one) were fed as short sound clips into a DMDX presentation and were distributed across two lists using a Latin-square design. Each experimental item was played twice: either the actual recorded sentence immediately followed by the cross-spliced version of the same experimental item or the reverse order - the manipulated version was played before the actual recording, depending on which list the particular participant received. For each list, the experimental items were divided into two blocks and each block was randomized separately. Participants were instructed that they would have to listen to spoken sentences, played via headphones as short sound-clips from the computer. In addition to this, they were told that they would be presented with a sequence of nearly identical sentence-pairs and that for each pair, one of them had been tampered with. The participants were instructed that they had to decide which of the spoken sentences sounded more natural to them by pressing the number keys "1" or "2" for the first or the second sentence respectively (see Figure 4 below).
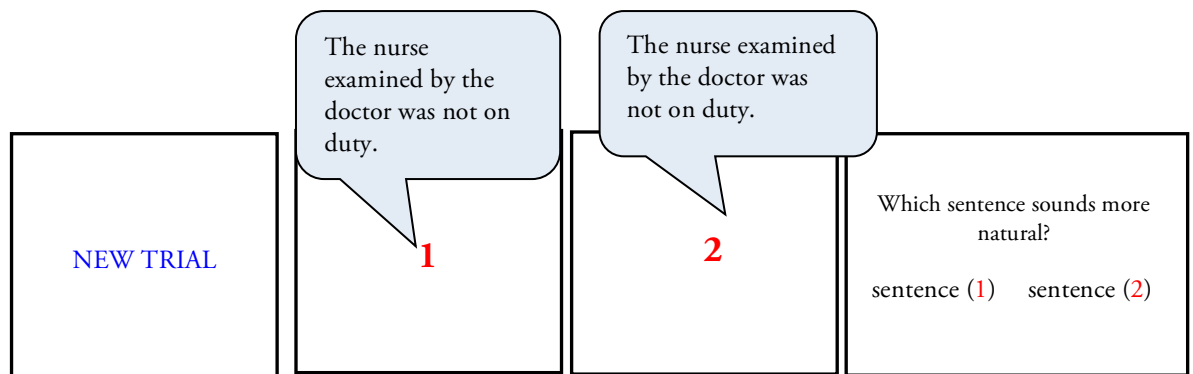
*Figure 4: Illustration of experimental sequence*

### 3.3.2 Results

We used a two-tailed binomial test to determine if the perceived naturalness differed significantly from chance for each item version. The participants showed no preferences towards one or the other version of the experimental items; in fact, there was a slight preference towards the manipulated version: 52% of the time, participants favoured the manipulated version while 48% of the time they perceived the originally recorded sentence as more natural (see Table 1 for frequencies and results of the binomial test, illustrating the two different presentation orders of List 1 and List 2). Hence, we can conclude that cross-splicing of the auditory stimuli in the critical *reduced relative clause* condition had no effect whatsoever on the perceived naturalness of the resulting sound clips.

*Table 1: Probabilities of perceived "naturalness" for the manipulated and un-manipulated reduced-relative clause conditions*

**Order = 1**

**Binomial Test (b)**

| | | Category | N | Observed Prop. | Test Prop. | Asymp. Sig. (2-tailed) | Exact Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|
| Answer | Group 1 | 0 | 165 | .52 | .50 | .615(a) | .615 |
| | Group 2 (recorded version) | 1 | 155 | .48 | | | |
| | Total | | 320 | 1.00 | | | |

a  Based on Z Approximation.
b  Order = 1

**Order = 2**

**Binomial Test(b)**

| | | Category | N | Observed Prop. | Test Prop. | Asymp. Sig. (2-tailed) | Exact Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|
| Answer | Group 1 | 1 | 166 | .52 | .50 | .539(a) | .539 |
| | Group 2 | 0 | 154 | .48 | | | |
| | Total | | 320 | 1.00 | | | |

a  Based on Z Approximation.
b  Order = 2

## 3.4 Participants EEG Experiment 1

Participants for Experiment 1 were 32 right-handed, native monolingual speakers of British English, 18 females (18-26 years, mean age 20.8) and 16 males (18-35, mean age 21.8) who were all recruited from the University of Glasgow subject pool.

Only those people were selected who had not participated in the pre-test study of Experiment 1. All subjects had normal or corrected to normal vision, normal auditory acuity (self-report), and no history of neurological or speech-language impairments.

Prior to the experiment all participants gave informed consent in writing according to the Declaration of Helsinki and were paid for their participation (£12 - £15, standard payment of £6 per hour).

### 3.4.1 Design & Materials

For an ERP study compared to e.g. Eye-tracking, far more items are required per design-cell. Other ERP studies investigating sentence processing during the last decade have established that a number of at least 40 items per condition is necessary (see Van Berkum et al. 2004). As the pre-test confirmed that the cross-spliced experimental material were acceptable, all of the previous selected 128 item-condition pairs were used for the EEG experiment. As already mentioned, each experimental item employed two conditions: The so-called baseline condition, where no processing difficulty should occur (Condition 1) and the critical reduced-relative clause (Condition 2), expecting to elicit a typical garden-path effect. It is important to acknowledge that the two conditions were acoustically identical to each other. Although the EEG experiment had first been implemented in E-Prime 2.0, the pilot study revealed, that the timing of the E-Prime trigger pulses for the critical time-locked events through the interface of the EEG recording software was not accurate and most often delayed. Therefore it became necessary to re-implement the experiment using a different presentation software. For the auditory stimulus representation we therefore used Experimental Run Time System (ERTS) software (cf. Dutta, 1995). As ERTS can only present sound files with an 8-bit sample resolution, the original recorded sound files were converted from 16-bit to 8-bit sample resolution using a sound editing software (Adobe Audition 2). In addition to this, each sound file was cut into three separate files. This was done to define certain trigger points, i.e. the stimulus or event to which the later statistical analysis is to be time-locked. The trigger inputs facilitate the set-up of ERP measurements and help to identify the

brain's response to certain events (see Table 2 for critical trigger points). Triggers were sent for the earliest point of disambiguation (the preposition "by"), the "spill-over"-region at the following noun phrase, and at the sentence ending to account for sentence wrap-up effects.

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Table 2: Trigger (as indicated by "||") for baseline condition (1) and garden-path condition (2)

**_The nurse that was examined ||by the doctor ||was not on duty.||_**

**_The nurse examined ||by the doctor ||was not on duty.||_**



Trigger 1 (word onset "by")

Trigger 2 (word onset "was")

Trigger 3 (end of sentence)

---

For the presentation the three-part sound files were played in consecutive order without any time delay, such that the listener was under the impression that just one single sound clip was played. The 128 experimental items (see Appendix A) were counterbalanced between two lists, in that each list contained the experimental items in just one of the two conditions (e.g. list one presented item 1 in condition (1) and item 2 in condition (2), whereas list two had item 1 in condition (2) and item 2 in condition (1)). In addition to this, 150 Filler sentences were pseudo-randomly interspersed between the experimental items of list 1 and list 2 (278 items per list in total), ensuring that between each experimental item there were at least two filler items. The filler items were created to employ simple declarative sentences of roughly the same length (see Appendix A for full materials).

### 3.4.2 Apparatus

Participants were seated in an electrically shielded and sound-attenuated booth with low-level ambient light. They were seated at a distance of approximately 90 cm from the Sony 15″ monitor and maintained throughout the experiment by means of a chin rest. Additionally, participants were instructed to move as little as possible during the experiment. They were told that they would have to listen carefully to spoken sentences and that sometimes the spoken sentence would be followed by a short comprehension question, visually presented on the computer screen (16 point Helvetica font in black on a white screen). The comprehension questions were answered by pressing the number key "1" for "YES" and "3" for "NO". Before the actual experiment started, a practice session was completed allowing the participants to get used to the task and to ensure that they understood it.

### 3.4.3 EEG-recording

A BIOSEMI Active Two amplifier system was used for continuous recording of electroencephalographic (EEG) activity from 72 Ag/AgCl electrodes according to the extended International 10–20 system, including electrodes for recording horizontal and vertical eye movements. Two additional electrodes (Common Mode Sense [CMS] active electrode and Driven Right Leg [DRL] passive electrode) were used as reference and ground electrodes. EEG and EOG (eye blinks and eye movements) activity were sampled at 256Hz. In addition to this there were two non-standard positions per hemisphere (left: PO9', O9', right: PO10', O10') which are located 33% and 66% off the M1-Iz / M2-Iz midline, respectively. The standard reference electrode was the left mastoid, however the data files were offline re-referenced to an average reference (an illustration of the channel layout can be found in Appendix A.2).

The experimental procedure took place as follows: Participants started each trial by pressing the <SPACE>-bar on the keyboard. Before the actual sound file was played, a fixation cross was presented in the centre of the screen and stayed there for 500ms.
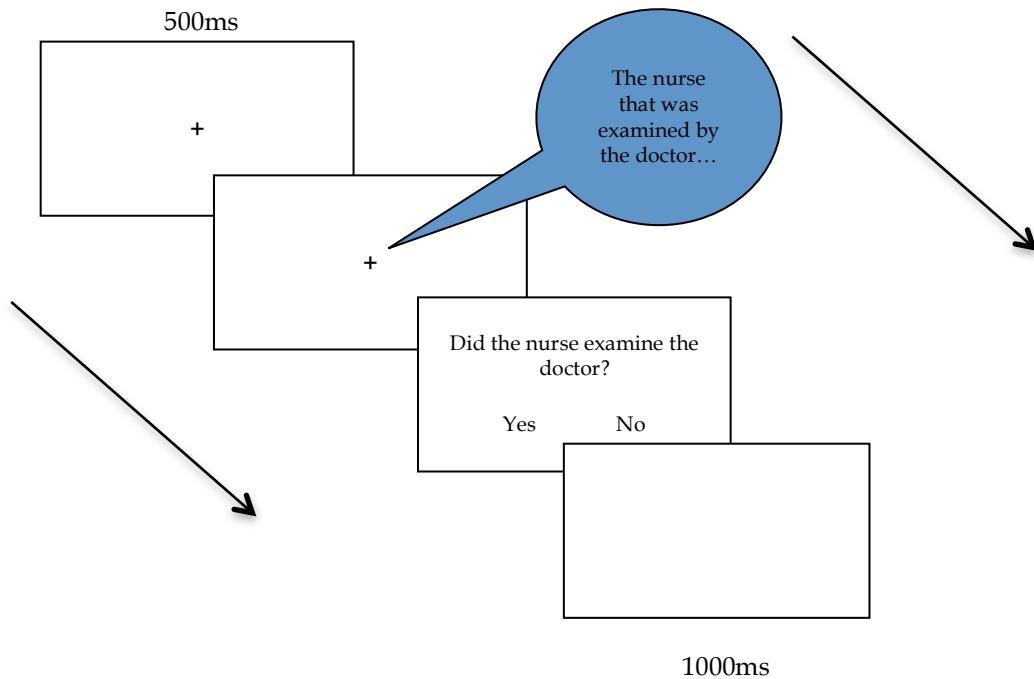


Figure 5: Schematic diagram of the experimental procedure

Participants were instructed to look at the fixation cross and to passively listen to the spoken sentence. As each trial just lasted about $2 - 3$ seconds, the participants were asked to avoid eye blinking while they were listening to the spoken sentences. They were explicitly encouraged to blink between trials. After 25% of the experimental trials and 50% of the filler items, the spoken sentence was followed by a simple "Yes/No"-comprehension question. This question required a non-speeded keyboard response, i.e. the question stayed on the screen until the participant answered it by pressing number key "1" for "YES", or "3" for "NO". After that, a blank screen was presented for 1000ms (the ISI). The 278 items were split into six blocks, of which four blocks employed 46 items and two block employed 48 items. Each block started with at least one filler item and was separated by a break. The duration of the break was determined by the participant as they triggered the next block by pressing the <SPACE>-bar. Before the

actual experiment started, there were eight practice trials to familiarize the participants with the procedure. After the practice session the experimenter answered any remaining questions.

### 3.4.4 Data analysis

EEG data were corrected offline for eye-movements, blinks, and non-ocular artifacts (drifts, channel blocking, and excessive EEG activity (exceeding $\pm$ 120 $\mu$V)) using the BESA software package (MEGIS Software (Ille, Berg, & Scherg, 2002)). Artifact correction is typically performed in order to extract unwanted signals the data. In order to do so, artifacts must be isolated from brain topographies while leaving the brain activity of interest as unaffected by this as possible. The method applied here used an adaptive artifact correction approach as implemented in BESA. Specifically, the BESA automatic artifact correction estimates brain activity based on the data currently displayed on-screen, which is then scanned in specified time intervals.

This algorithm then considers segments to represent brain activity where either the correlation between data and artifact topography does not exceed a previously specified threshold and the signal amplitudes itself do not go beyond a certain threshold. Following this, the remaining segments are subject to a principal component analysis (PCA). The PCA components accounting for more than the minimum variance specified by the BESA 'Adaptive Model: PCA Topography' are then retained and are assumed to cover the brain signal subspace. Based on these topographies, the data is decomposed into a linear combination of brain and artifact activities and the estimated artifact signals can be subtracted from the original signals with very little distortion. This approach is recommended for the inspection of continuous EEG or MEG data (see Ille, Berg, & Scherg, 2002).

The resulting data files were re-referenced offline to the average reference of the 72 channels. To account for filter artifacts, time segments of 12 seconds (6s before and 6s after stimulus onset) were exported to the Fieldtrip toolbox (http://www.ru.nl/fcdonders/fieldtrip) and filtered using a low-pass filter of 30Hz for the ERP analysis, whereas for the TFR data only a dft-filter was applied to remove line noise at 50Hz, 100Hz and 150Hz. A baseline correction from -200ms to the onset of the critical word was applied to ERP and TFR data on the single-trial level. After preprocessing, EEG data were then segmented from -200 to 1000ms relative to the onset of "by" (the earliest point of disambiguation), "was" (to capture spill-over effects), and the end of the sentence (to look for sentence wrap-up effects) for subsequent timelock-analysis and time-frequency-analysis. All analysis as well as plotting of the results was done using the Matlab toolbox Fieldtrip (can be downloaded at http://www.ru.nl/fcdonders/fieldtrip) and self-written Matlab codes.

### 3.4.5 Statistical analysis

The significance of the difference between the garden-path condition and the non-ambiguous control (time-locked with "by", "was", and the end of the sentence) was determined both for TFRs and ERPs by means of a non-parametric randomisation test implemented as Cluster Randomisation Analysis in the Fieldtrip toolbox (Maris & Oostenveld, 2007). This test effectively accounts for the multiple comparison problem (such as 72 channels and multiple time-points) by computing two-sided t-tests (p = 5%) for the difference between the conditions for neighboring (channel x time) - pairs (ERP analysis) or (channel x frequency x time) - pairs (TFR analysis). The neighboring channel-time or channel-time-frequency pairs that exhibit the same direction of effect are clustered. The cluster with the maximum sum is used as the cluster-level test statistic under the randomisation null distribution. Here, the randomisation null distribution was

obtained by randomizing the order of the grand-average data of the relevant conditions within every participant. This reference distribution of cluster-level t statistics was created from 1000 randomisations. The p-value was estimated according to the proportion of the randomisation null distribution exceeding the observed maximum cluster-level test statistic (the so-called MonteCarlo p-value). By creating 1000 random draws, this Monte Carlo p-value is an accurate estimate of the true p-value.

The analysis method described above can provide a far more complete and informative way of analysing EEG data without any a-priori bias on certain time periods or scalp locations. This is not to suggest that this analysis method cannot be incorporated with purely hypothesis-driven approaches as well as with well-established ERP components in the language domain.

### 3.4.6 ERP results

***Timelock-Analysis at "by":***

The non-parametric cluster randomisation analysis revealed a biphasic ERP-pattern when comparing the garden-path condition to the non-ambiguous control condition in a time window starting of 0 – 900ms post-stimulus: The analysis found one negative cluster (p < 0.01, time = 0.29 to 0.41 sec) over central electrodes, which was more pronounced over the right hemisphere.
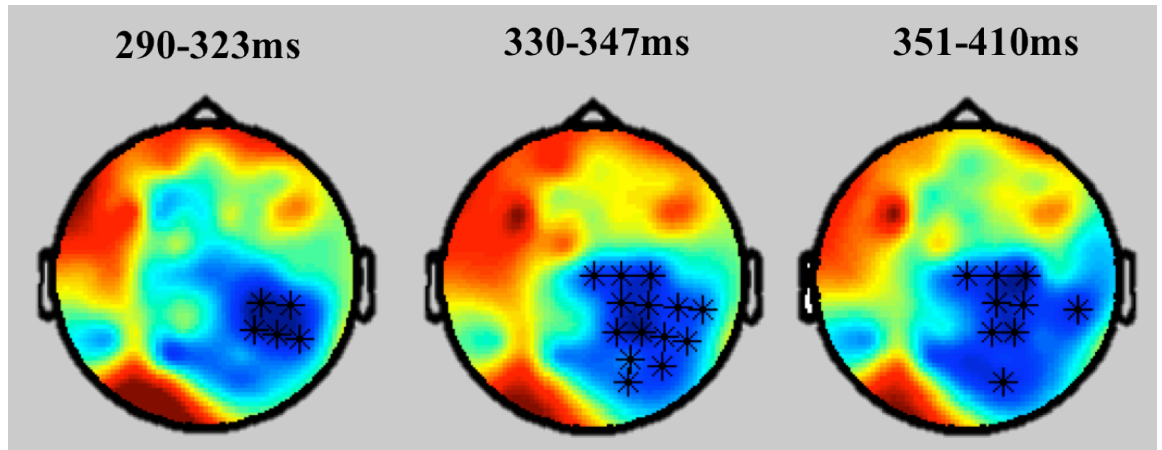
*Figure 6: Topographic plots of the statistical significant difference between the Garden-path conditions compared to their unambiguous control at the point of disambiguation ("by") in the N400 time window (290ms – 410ms, top to bottom). Statistical significant time\*electrode-clusters are highlighted with ' \* '*

This effect was followed by a posterior positive cluster ($p < 0.04$, time = 0.49 to 0.63 sec) over parietal electrodes. Due to their latency and their topographical surface distribution, it is possible to relate the posterior cluster to the traditional P600 effect (see Figure 7), while the negative cluster in the preceding time-window suggests a response similar to a N400 (see Figure 6). Note that the N400 in response to words in speech tends to have an earlier onset and is typically less peaked than those during reading, which makes accurate latency estimates difficult.
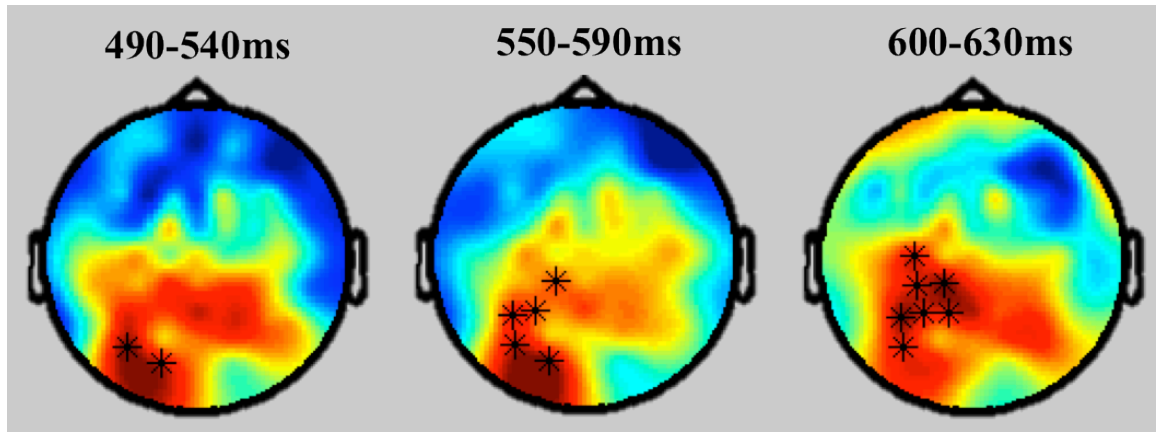
*Figure 7: Topographic plots of the statistical significant difference between the Garden-path conditions compared to the unambiguous control at the point of disambiguation ("by") in the P600 time window (490-630ms, top to bottom). Statistical significant time\*electrode clusters are highlighted with a '\*'.*
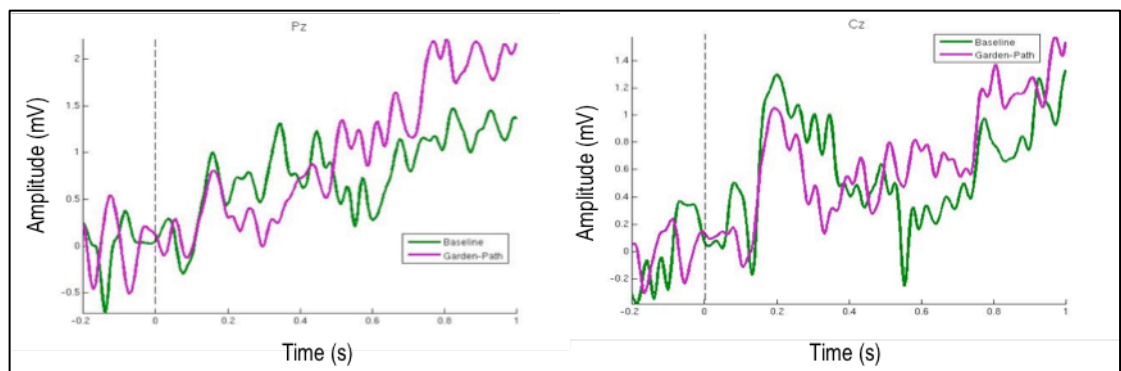


*Figure 8: Grand average ERPs at centroparietal (Pz) and central (Cz) electrodes from 32 participants at the point of disambiguation (the preposition "by"). The 'pink' line depicts the garden-path condition and the 'green' line depicts the unambiguous control condition (baseline condition). The grand average illustrates a larger N400, which was followed by a larger positivity for the garden-path condition compared to the control condition.*

### Timelock-Analysis at "was" and the sentence ending:

None of the analysis revealed any significant effects, neither in the spillover region nor at the sentence ending (p> 0.2)

### 3.4.7 Results of TFR analysis

Oscillatory components in the ongoing EEG or MEG signal often show power changes relative to experimental events. As described in chapter 1.4, these signals are not necessarily phase-locked to the event and will not be represented in event related fields and potentials. We hypothesized that if *linguistic conflicts* triggers *domain-general* mechanisms involved in error detection, conflict monitoring, and working memory, this should result in increased activity in domain-general networks such as PFC for the garden-path condition compared to the unambiguous control (at "by"). To establish which frequency bands might exhibit significant power changes, a wavelet-based time-frequency analysis was conducted in a wide frequency range using a multitaper approach as implemented in the fieldtrip toolbox with a frequency resolution of 2Hz (1-80Hz). Typically, multitapers are applied in order to achieve better control over the frequency smoothing. Using more tapers for a given time window will result in greater frequency smoothing. High frequency smoothing has been shown to be particularly advantageous when dealing with fast oscillations above 30 Hz. For instance, oscillatory gamma activity (30-80 Hz) benefits from multitapering. For signals lower than 30 Hz it is recommend to use only a single taper, e.g. a Hanning taper.

After visually identifying the effects in the theta (4-7Hz) and beta (16-26Hz) frequency spectrum, a subsequent time-frequency analysis for these two frequency bands was conducted separately by applying a frequency-dependent sliding time window using a Hanning taper and a frequency resolution of 1Hz. The length of the window was at least five cycles (i.e., $\Delta T = 5$ / foi, where foi is the frequency of interest). The data from each sliding time window were multiplied with five orthogonal Hanning tapers. The data was baseline-corrected on the single-trial level using data in the time window 0.2s before the critical word onset ("by"). Subsequently, the data were Fourier-transformed and the power spectral densities were averaged.

Nonparametric permutation tests identified clusters of activation in time, frequency, and sensor space: Time-frequency analysis of power revealed a significant cluster of theta-band power increase with a surface effect with activation predominantly over frontal-midline electrodes and a weaker activation over parietal electrode sites (4-7Hz, 200ms-580ms post-"by"; p=0.002). Interestingly, this theta effect was preceded by a very early and short-lived decrease of beta-activity, which was also located over frontal-midline electrodes (16-26Hz, 50ms-180ms post-"by"; p=0.009) for (1) as opposed to (2) (see Figure 8 below for the mean raw effect).
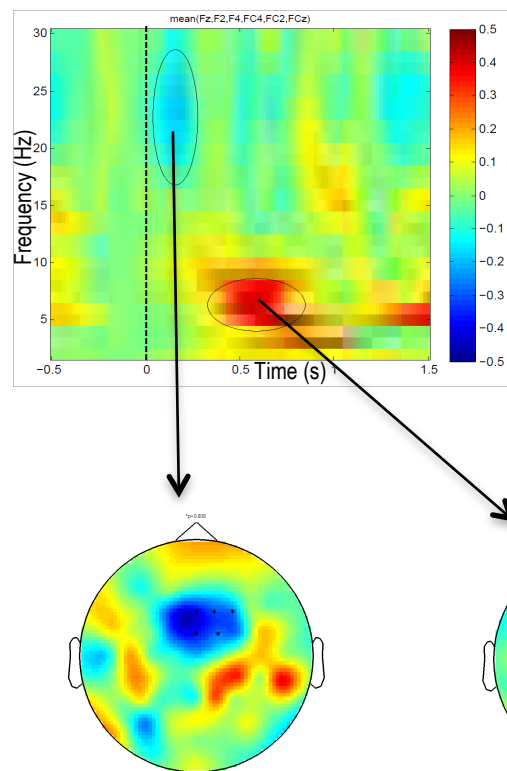


Figure 9: Mean raw effect of beta decrease (16-26Hz) followed by theta increase (4-7Hz) over representative frontal-midline electrodes. The dashed line indicates the onset of the preposition "by". Regions with warmer (red) colours indicate a power increase relative to baseline; regions with cooler (blue) colour reflect a power decrease.
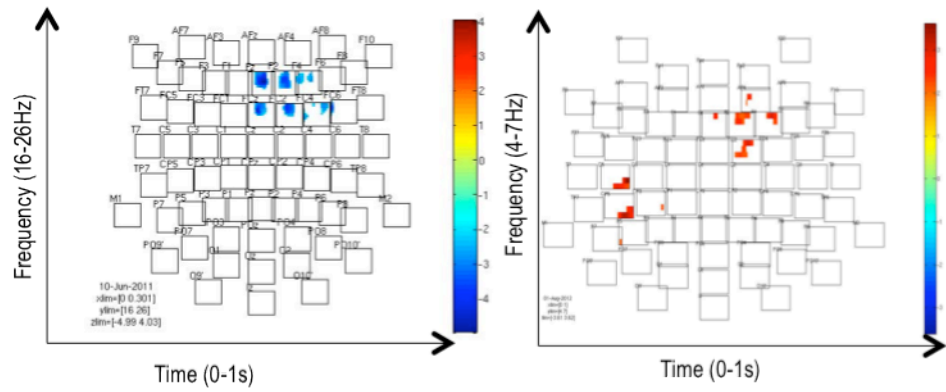
*Figure 10: Left-hand side depicts the masked significant surface effect of the decrease of beta activity over frontal-midline electrodes. Right-hand side depicts the masked significant surface effect of the theta increase over frontal-midline and parietal electrodes (please note that each square denotes one electrode). Regions with warmer (red) colour indicate a power increase relative to baseline; regions with cooler (blue) colour reflect a power decrease.*

### 3.4.8 Source localization: Method

The source localization of the significant time-frequency clusters in the theta and beta band first required aligning the participant's individual electrode positions to the cortical mesh of a standard BEM model. The standard BEM model is derived from a standard structural magnetic resonance image using a rigid body-transform (Besl and McKay, 1992).
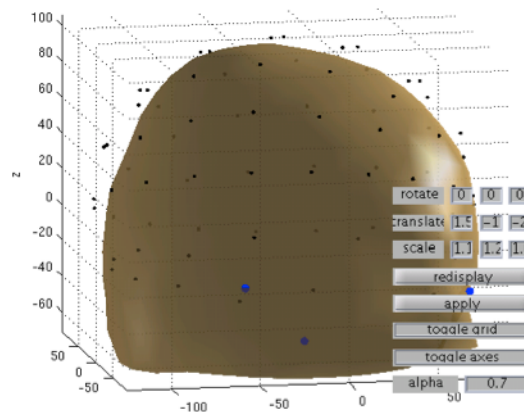


*Figure 11: Illustration of the alignment of the electrode positions to the cortical mesh of the standard BEM model.*

To localize the sources of the theta- and beta-band activity, a Multiple-Source DICS Beamformer approach was used as implemented in Fieldtrip. This method identifies the sources responsible for producing this oscillatory activity by applying a beamformer technique. This technique employs a spatially adaptive filter, which allows to estimate the amount of activity at any given location in the brain. To do so, the brain is divided in a regular three-dimensional grid and the strength for each source at each grid point is computed. The method applied here is the Dynamical Imaging of Coherent Sources and the estimates are calculated in the frequency domain (Gross et al. 2001). This algorithm allows to image evoked and induced oscillatory activity in a user-defined time–frequency domain. The Beamformer computes the changes of power in a post-stimulus interval relative to a pre-stimulus baseline (set to 200 to 0 ms prior to stimulus onset), transforming the data into standard MNI space (Montreal Neurological Institute, Montreal, Quebec, Canada). Beamformer source analysis was performed for each cycle in the baseline and garden-path condition separately, but only for those time–frequency windows that exhibited significant effects in the interaction analysis on the scalp electrode level.

The beamforming approach (Figure 12) relates the decreased frontal-midline beta activity (DICS-center frequency: 20Hz), or more precisely the *local maxima*, to the anterior cingulate cortex (ACC, MNI coodinates [8, 24, 40]), the right temporal lobe (BA 38, MNI coordinates (50, 11, -11)), the left temporal lobe (BA 20, MNI coordinates (-56, -40, -24)), and the left middle occipital gyrus (BA 19, MNI coordinates (-32, -80, 16)). The increase in theta activity (Figure 12.B.; DICS center frequency: 6Hz) for the garden-path conditions compared to their unambiguous control localized in the right superior frontal gyrus (BA 6, (25, 18, 57)), the left parietal lobe (BA 7, MNI coordinates (-27, -49, 69)), and the right occipital lobe (BA 18, MNI coordinates (9, -92, 20)).
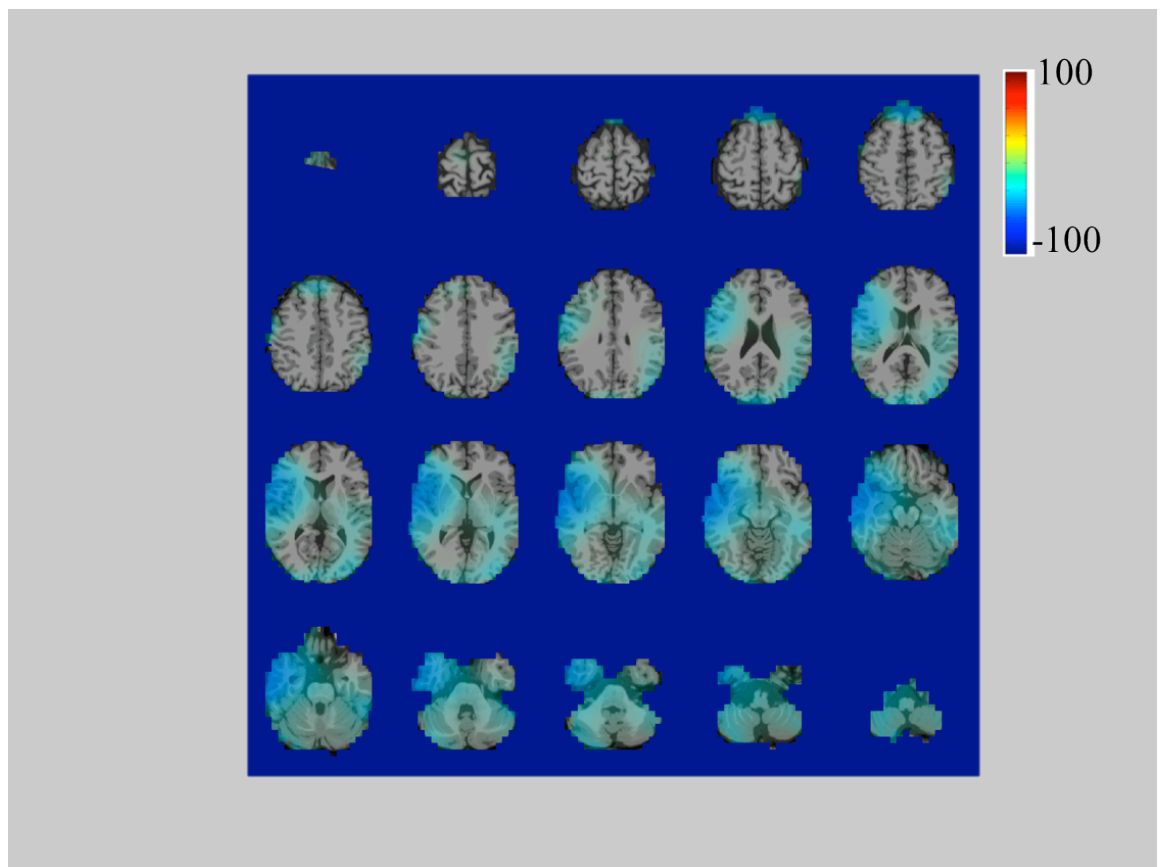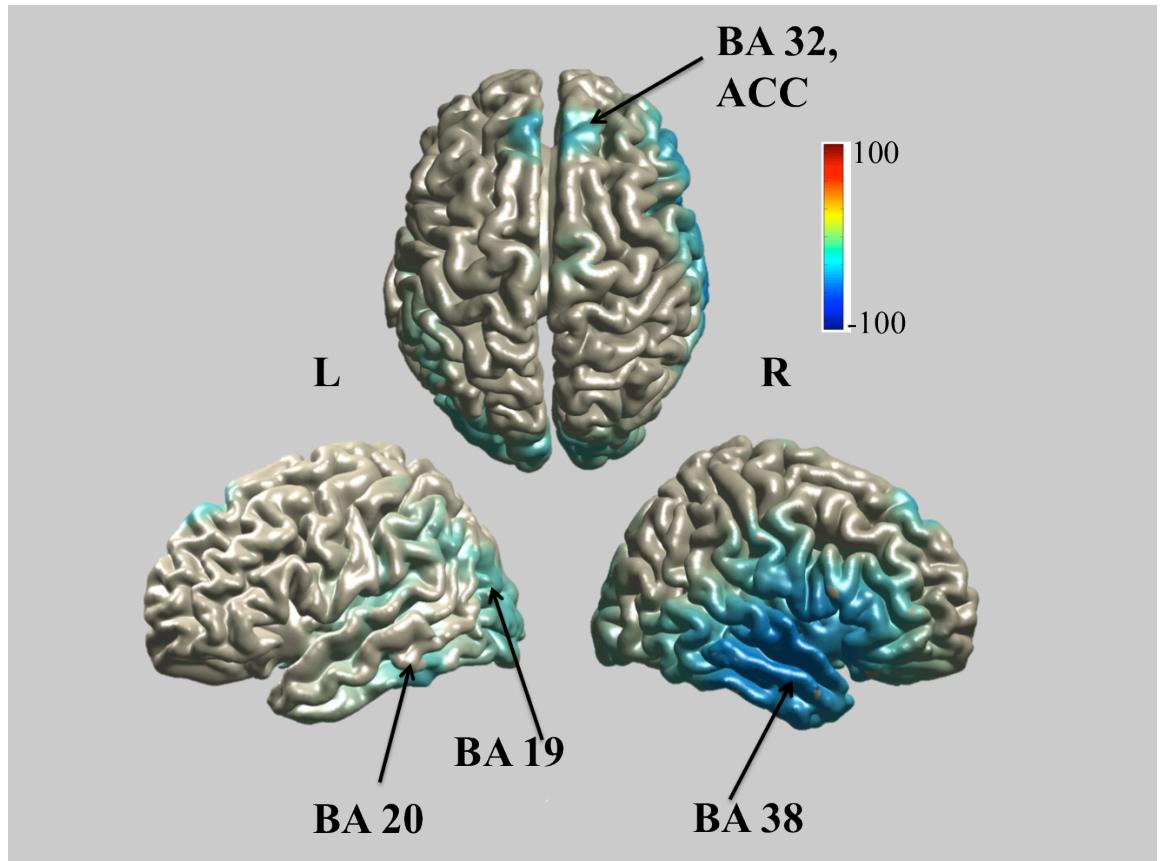
*Figure 12: Top: Source Activation maps projected on an inflated surface of the beta power decrease (16-26Hz) for the garden-path conditions compared to their correct control in the ACC (BA 32), the right superior temporal gyrus (BA 38), the left temporal lobe (BA 20), and the left occipital lobe (BA 19). Regions with cooler (blue) colour reflect a power decrease. Bottom: 2D-slice visualisation of the beta effects.*
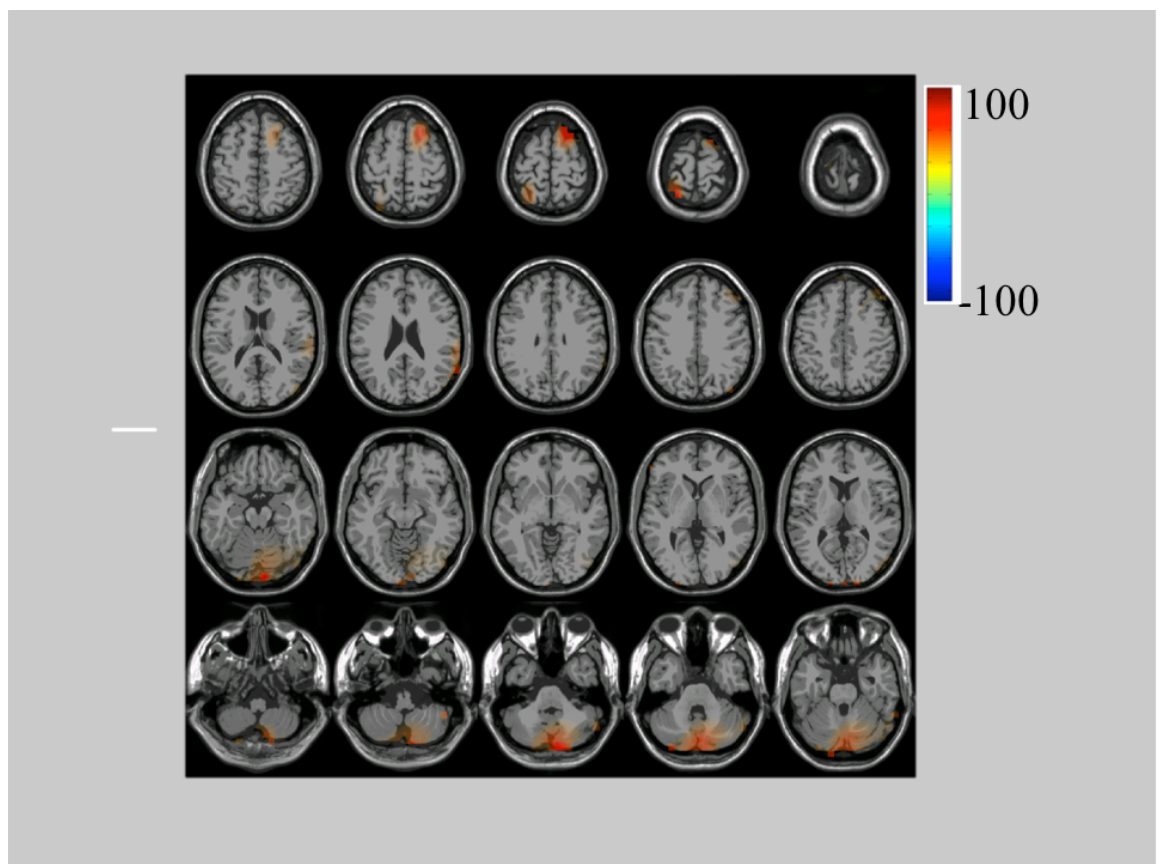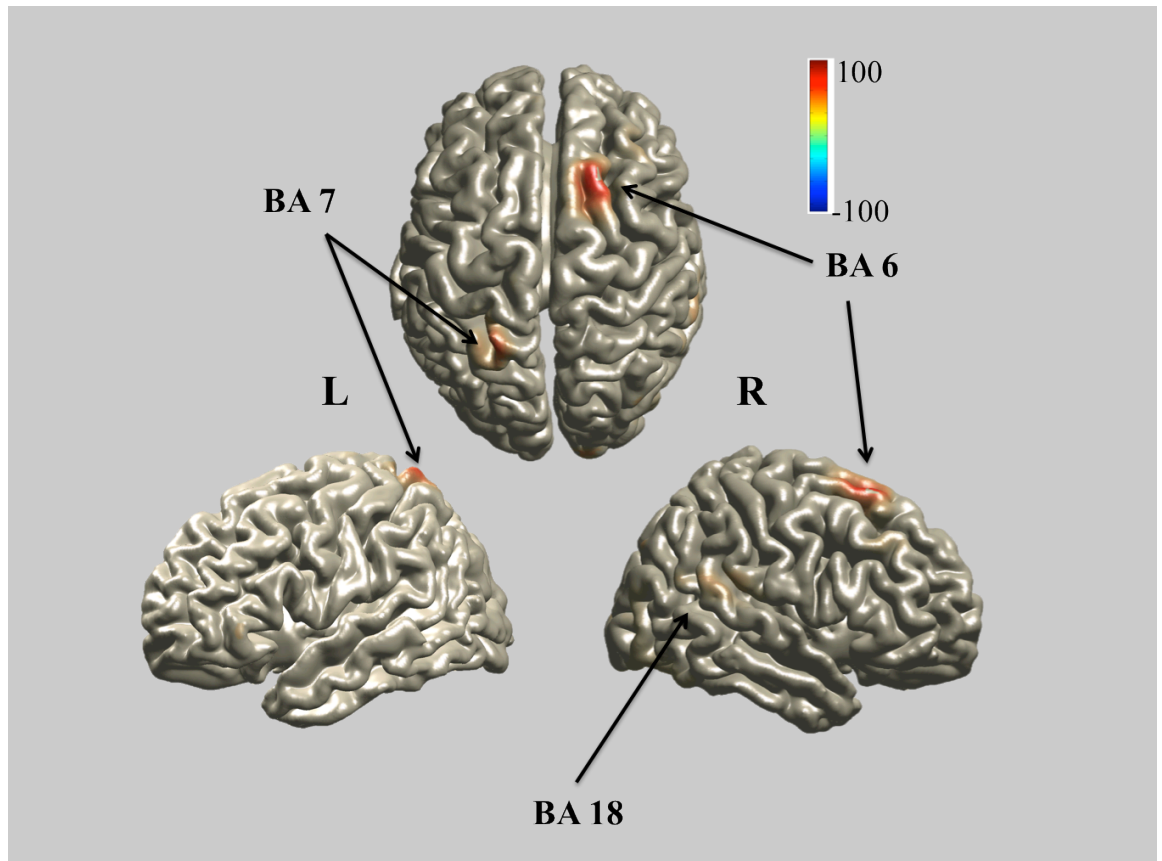
*Figure 13: Top: Source Activation maps projected on an inflated surface of the theta power increase (4-7Hz) in the right superior frontal gyrus (BA 6), the right occipital lobe (BA 18; bottom right), and the left parietal lobe (BA 7; bottom left figure). Regions with warmer (red) colours indicate a power increase relative to baseline; regions with cooler (blue) colour reflect a power decrease. Bottom: 2D-slice visualization of the significant sources.*

| Contrast | Frequency | Latency post-stimulus | BA | Significance (*) | (x  y  z) [MNI] | Local Maxima [Talairach] |
|----------|-----------|-----------------------|----|------------------|------------------|--------------------------|
| Gardenpath - Baseline | Theta (4-7Hz) | 200-580ms | 6 | p = 0.002 (*) | (25, 18, 57) | Right Cerebrum, Frontal Lobe, Superior Frontal Gyrus, Range = 1 |
| | | | 7 | p = 0.002 (*) | (-27, -49, 69) | Left Cerebrum, Parietal Lobe, Postcentral Gyrus, Range=4 |
| | | | 18 | p = 0.002 (*) | (9, -92, 20) | Right Cerebrum, Occipital Lobe, Cuneus, Range=0 |
| Gardenpath - Baseline | Beta (16-26Hz) | 50-180ms | 32 | p=0.009 (*) | (8, 24, 40) | Right Cerebrum, Limbic Lobe, Cingulate Gyrus, Range=1 |
| | | | 38 | p=0.009 (*) | (50, 11, -11) | Right Cerebrum, Temporal Lobe, Superior Temporal Gyrus, Range=1 |
| | | | 20 | p=0.009 (*) | (-56, -40, -24) | Left Cerebrum, Temporal Lobe, BA 20, Range=3 |
| | | | 19 | p=0.009 (*) | (-32, -80, 16) | Left Cerebrum, Occipital Lobe, Middle Occipital Gyrus, Range=2 |

*Table 2: Summary of the significant effects of the time-frequency analysis at the earliest time-point of disambiguation (the preposition 'by)', and the localization of the effects as indicated by coordinates in MNI space. These coordinates were translated into their corresponding Talairach coordinates.*

## 3.5 Discussion

As the garden-path model suggests, we found a biphasic pattern in the ERP profile for the garden-path condition compared to the unambiguous control. Surprisingly, this was not reflected in a LAN-P600 complex as implied by Friederici's neurocognitive model of sentence comprehension. Instead, we observed an N400-P600 complex at the earliest point of disambiguation. One might argue that the negativity effect may in fact represent a LAN instead of a N400. However, based on its topographical distribution (centro-parietal and more pronounced over the right hemisphere), the interpretation towards a classical N400 appears more accurate. The fact that an N400 followed by a

P600 is elicited shortly after the disambiguating word "by" is most consistent with models of sentence comprehension that stress the immediate and online nature of language comprehension, as for instance Hagoort's MUC model (2003, 2005). Van Petten & Luca (2012) recently pointed out, that over the last three decades there has been a substantial number with biphasic N400-P600 ERP responses to what appear to be fairly conventional semantic manipulations. It has also been suggested that multiple ERP components with different spatial distributions across the scalp are indicative of different neural generators.

The N400 component here might possibly be related to the syntactic unexpectedness of the incoming material due to incorrect *thematic role assignment* (Bornkessel & Schlesewsky, 2006). Others have suggested that the N400 is indicative of failed predictions, i.e. disconfirmation of a strong expectation should elicit a larger N400 compared to a correct control (e.g. Federmeier, 2007).

In line with our assumptions we found activation in areas associated with domain-general mechanisms of executive control in the frequency profile: The very early transient decrease of beta activity with its local maximum in the ACC, might be indicative of the error detection process due to failed expectations. Recently, Arnal and Giraud (2012) have suggested that beta oscillations may play a part in predictive timing and in top-down broadcasting of content specific predictions (Engel & Fries, 2010). Interestingly, Arnal and Giraud proposed that error-related effects result in modulations in the beta band. Specifically, when explicit expectations are violated, beta oscillations are first suppressed (or desynchronized) and then resynchronized, resulting in an increase of beta power (the so-called 'beta rebound'). This may also apply to the locally ambiguous reduced-relative clause at hand, as theses sentences typically strongly favour a main clause interpretation during initial processing, resulting in an error signal due to failed expectations. Although the non-parametric randomisation test did not identify a beta rebound in our analysis window (0-1s post-stimulus), the raw effect (see Figure 8)

suggests that indeed, there might be an increase in beta power just outside our analysis window. In addition to this, we found significant sources in the right temporal lobe (BA 38) and the left temporal lobe (BA 20), which are most likely caused due to the auditory stimulation.

The later theta increase activates areas associated with working memory demands, namely the right superior frontal gyrus (BA 6, which contributes to the dorsolateral prefrontal cortex), the left parietal cortex (BA 7) and the right occipital lobe (BA 18).

This network is assumed to reflect the interplay between executive functions and retrieval of information from domain-specific storage. BA 6 is also assumed to play a role in Working Memory, which is in agreement with the assumption that syntactically ambiguous sentences impose increased load on working memory demands.

In conclusion, our results suggest that executive control is a general mechanism that not only regulates attention and perception, but also extends to resolve competing sentential interpretations in language processing. Consistent with the existing literature, these processes are reflected in increased large-scale activation throughout the cortex and appear to be mediated by the superior frontal gyrus (BA 6) and the ACC.

# 4. Conflicts induced by a gender-mismatch in anaphoric and cataphoric pronoun resolution

## 4.1 Introduction

Establishing co-reference with, for instance, a pronoun which refers back to a noun mentioned earlier in the sentence, has often been used in order to understand how language comprehension takes place. For quite some time, linguists, psycholinguists, and neuroscientists have focused on the underlying cognitive and neural mechanism of co-reference, as well as what kind of information is accessed during the comprehension of anaphoric expressions (Swaab, Camblin, & Gordon, 2004; Schmitt, Lamers, & Münte, 2002; Gordon & Hendrick, 1998; Osterhout, Bersick, & McLaughlin, 1997; Carreiras, Garnham, Oakhill, & Cain, 1996; Hankamer & Sag, 1976). These studies have produced a reasonable amount of literature based on behavioral data (see Chomsky, 1981, 1986; Fodor, 1989; Garnham, 2001; Garrod & Sanford, 1994; Nicol & Swinney, 2002; Trueswell & Tanenhaus, 2005 for reviews) which inspired a number of linguistic theories of anaphora (e.g. Ariel, 1990, 1991; Chomsky, 1981; Givon, 1982; Murphy, 1985; Reinhart & Reuland, 1993), as well as psycholinguistic models of anaphoric processing (e.g. Almor, 1999; Garrod & Sanford, 1994; Garrod & Terras, 2000; Gordon & Hendrick, 1998). In the last 30 years, researchers have also begun to use neurophysiological methodologies in order to test previously established theoretical claims about anaphora resolution.

Many of the studies employing anaphoric constructions did not specifically investigate anaphoric processing: rather, anaphoric constructions were used to investigate other questions, primarily questions about the nature of the underlying parsing mechanisms. In a similar line of thought we will use anaphoric constructions to investigate how sentence context information is used during linguistic conflict resolution. A substantial body of literature suggests that the brain immediately uses context to

predict features of likely upcoming items (e.g. Federmeier et al., 2007; Van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005; Wicha, Bates, Moreno, & Kutas, 2003; Wicha, Moreno, & Kutas, 2003, 2004). In two EEG experiments we are investigating the real-time processing of conflicts in anaphoric relations using a well-studied gender-mismatch paradigm in a weakly constraining sentence context compared to a strongly constraining sentence context (anaphora and cataphora contexts respectively); the latter context type was expected to lead to strong predictions for a particular sentence completion.

Gender information can occur in various locations within the sentence. Typically, gender-marking is used to compute long-distance relations between elements in a sentence and it is usually expected that all gender-marked elements agree. Several studies on gender agreement have demonstrated that readers immediately slow down when an anaphoric reflexive (*herself*) refers to an antecedent (*king/minister*) that mismatches its gender (Carreiras et al., 1996; Kennison, 2003; Sturt, 2010; Duffy & Keir, 2004, Kreiner et al., 2007; Osterhout et al., 1997). These effects are due to a conflict between the gender of the pronoun and the gender of the co-referring noun. The mismatch effect is typically associated with longer reading times in Eye-tracking and Self-paced reading. Osterhout et al. (1997) reported additional ERP-evidence for a gender mismatch effect during reading comprehension. They measured ERPs while readers processed sentences that contained either a lexically gender-marked word (e.g., *mother, father*) or a stereotypically gender-marked word (e.g., *doctor, nurse*) as an antecedent noun for the reflexive pronouns *himself* or *herself* ([10a], [10b]):

[10a] "The nun criticized himself/herself…"

[10b] "The doctor criticized himself/herself…"

Osterhout and colleagues observed a centro-parietal positivity (P600) with greater amplitude at the reflexive position when the gender of the reflexive pronoun mismatched the gender of the antecedent than when the gender of the reflexive pronoun and antecedent matched. In addition to this, the gender-mismatch effect was stronger in the lexically marked conditions than in the stereotypically marked conditions', as indicated by a larger amplitude of the P600-effect at the mismatching reflexive.

Most research trying to clarify this issue used anaphora sentences, where the antecedent precedes the referring pronoun (but cf. Banaji & Hardin, 1996). Within a sentence, an anaphor typically follows its antecedent. However, under certain circumstances (not only in English but also in many other languages), anaphors can precede their antecedents. Only few studies have used these so-called *cataphoric* sentences (also referred to as *backwards anaphora*), either using self-paced reading or eye-tracking (Kazanina, 2007, Van Gompel & Liversedge, 2003). No electrophysiological studies except for ours has been conducted using these types of stimuli. Anaphora and cataphora obviously differ concerning the linear order in which the pronoun and co-referential noun appear. This may influence the conflict resolution strategies for the different sentence types (Kazanina et al., 2007), because in cataphora sentences the pronoun / reflexive unambiguously determines the gender of the relevant discourse referent *before* the critical noun is actually processed.

Van Gompel and Liversedge (2003) for instance recorded participants' eye-movements while they read sentences containing cataphoric pronouns (see example (11)):

(11) *When she was fed up, the (girl/boy) visited the (boy/girl) very often.*

The stimuli employed a gender-marked pronoun in a preceding adverbial clause (*he* or *she*), which was either in agreement or disagreement with the gender of

the main clause subject (*the boy* or *the girl* in this case). Analysis of the eye-tracking data revealed that participants slowed down at or shortly after the main clause subject in the matching conditions relative to the mismatching conditions.

According to Van Gompel and Liversedge's *feature delay hypothesis* (2003), the processor initiates a referential dependency before the gender information of the main clause subject has been determined. In the context of incongruent conditions where the initial dependency has to be abandoned, this will result in a slow-down.

By contrast, it is also feasible to interpret these results with a predictive processing strategy: During the initial processing of the subordinate clause, the position of the main clause subject may be predicted ahead of time because the early pronoun signals an upcoming dependency formation (see also Illkin & Sturt, 2011). As a consequence, a referential dependency is established between the cataphoric pronoun and the anticipated subject which in turn leads to processing difficulties in the mismatching conditions when the gender of the predicted subject mismatches with the gender of the encountered noun. Resolving referential dependencies using a predictive processing strategy has been suggested by Kazanina et al. (2007) and termed 'Active Search'. This gender mismatch effect is equivalent to ''active'' dependency formation effects that have been widely reported in studies examining the processing of wh-dependencies (e.g., Crain & Fodor 1985, Stowe 1986, Traxler & Pickering 1996; for a review, see Phillips & Wagers 2007). Kazanina et al. (2007) additionally showed that the mismatch effect disappears when the subject is ruled out as an antecedent position by c-binding principles (*binding principle C*, Chomsky, 1981).

Kreiner et al. (2008) adapted this 'Active Search' interpretation based on experimental data on cataphoric reference because they observed similar effects in an Eye-tracking study.

In the cataphora experiment, Kreiner et al. (2008) recorded eye-movements while participants read sentences such as those in (12a.-d.):


(12a.) **Stereotypical Gender: match**

　　　After reminding *himself* about the letter, the *minister* immediately went to the meeting at the office.

(12b.) **Stereotypical Gender: mismatch**

　　　After reminding *herself* about the letter, the *minister* immediately went to the meeting at the office.

(12c.) **Definitional / Lexical Gender: match**

　　　After reminding *himself* about the letter, the *king* immediately went to the meeting at the office.

(12d.) **Definitional / Lexical Gender: mismatch**

　　　After reminding herself about the letter, the king immediately went to the meeting at the office.


The experimental design manipulated both stereotypical gender-biased nouns (e.g. minister in (12a,b)), and also lexical (or definitional as they called it) gender nouns (e.g. king in (12c,d)). The difference between these two noun types is that lexical gender nouns such as *king* are male by definition, while stereotypical gender nouns such as *minister* or *nurse* are inferred by stereotypical inference and deduced through fit with the context. Stereotypical nouns can either be male or female, but there is certainly a bias towards a certain gender. Both gender noun types either matched or mismatched with the gender of their preceding reflexive.

Kreiner et al. (2008) observed a gender mismatch effect for the lexical gender conditions, resulting in longer reading times immediately following king in (12d) than in (12c). By contrast, no such effect was observed between the matching stereotype gender conditions (12a) and their mismatching counterpart (12b). In line with

Kazanina's (2007) suggestion, Kreiner et al. (2008) explained the absence of the gender mismatch effect for the stereotypical conditions in terms of a predictive processing strategy: The dependency formation between *himself / herself* and the co-referring stereotypical noun was created ahead of time, determining the gender of the subject noun before it was encountered.

For the lexical nouns they proposed that the mismatch effect can be accounted for under the assumption that gender information for these nouns types is retrieved via lexical access, leading to a slow-down due to a gender mismatch in the mismatching condition. Under the predictive dependency formation strategy, the early pronoun in the cataphora sentences signals an upcoming dependency formation, and consequently the gender of the co-referring stereotypical noun is determined before the stereotype role name is processed in the input. As a result, the gender is readily available, preventing the gender mismatch effect for (12a) compared to (12b) as stereotypical inference is rendered unnecessary.

In line with Kazanina et al. (2007) and Kreiner et. al (2008) we argue that conflicts caused by conflicting gender information are driven by predictive processing mechanisms. Analogous to the manipulation in Kreiner et al. (2008), we designed two EEG experiments using anaphora (Experiment 2 [13a–13d]) and cataphora sentences (Experiment 3, [14a–14d]), using a noun-reflexive (*anaphora*) and a reflexive-noun (*backwards anaphora* or *cataphora*) gender agreement manipulation where the gender of the reflexive was either congruent or incongruent with the gender of the co-referring noun. These quite simple linguistic variations allowed us to modulate the strength of linguistic predictions by designing a less predictive environment (anaphora) compared to an environment with strong expectations (cataphora). Similarly, we manipulated the strength of conflict by contrasting lexical - (e.g. *king*) with stereotypical gender nouns (e.g. *minister*), expecting a significantly stronger and longer lasting mismatch effect for the inherently definitional nouns.

In terms of ERP components related to gender mismatch paradigms in anaphora contexts, we can make certain predictions: Osterhout et al. (1997) observed P600-effects for lexical- as well as stereotypical role nouns that were paired with gender-incongruent pronouns compared to a matching control sentence. There was a quantitative difference of the gender mismatch effect between lexical- and stereotypical conditions: This was reflected in a stronger amplitude of the P600 component in the lexical conditions as compared to the P600 effect in the stereotypical conditions. However, if distinct processes control gender agreement with stereotypical compared to definitional role nouns, we would expect the different nouns to elicit distinct ERP signatures during the processing of gender agreement. As there have not been any neurophysiological studies employing cataphoric sentences yet, the electrophysiological outcome in terms of ERP components remains uncertain.

Concerning the oscillatory signature for gender agreement mismatches, we may expect modulations in the theta frequency band (4-7Hz): Bastiaansen et al. (2002b) investigated two different agreement manipulations in Dutch compared to a correct control (see chapter. 2.2.2), i.e. gender agreement violations and number agreement violations– both of which have shown to result in a P600 component in the EEG (van Berkum et al., 2000): They found for both violation types resulted in increased power in the theta frequency band (4-7Hz) in a latency range of 300-500ms after stimulus onset. The local maximum showed different distributions on the scalp surface: *gender agreement* elicited an increase in theta power over *right* anterior electrode site, whereas *number agreement* elicited a theta power increase over *left* anterior electrodes.

In terms of predictive processing strategies when faced with conflicting information, we expect activation in distinct networks in the frequency profile of anaphora compared to cataphora: As described in chapter 2.4, if linguistic information strongly cues future linguistic information – for instance a pronoun strongly predicting

the future occurrence of a noun with congruent gender (cataphora) – then linguistic processing and conflict resolution are expected to take place in an automatic fashion, resulting in activation of strongly localized, linguistic specific network such as temporal or parietal regions. However, if future information is less predictable or even uncertain based on context information - for instance a noun predicting only weakly the occurrence of a pronoun of the same gender – then the processing of conflicting information is expected to engage controlled processes: This should result in activation of cognitively general systems specialized in flexible conflict resolution and top-down cognitive control, primarily engaging large-scale networks in the dorsolateral prefrontal cortex (dLPFC), anterior cingulate regions (ACC), and parietal areas.

Another evidence for predictive processing mechanisms for both, ERP component as well as oscillatory effects, is the speed with which the relevant effects are observed (e.g. Lau et al. (2006), Dikker et al. 2009). Based on this assumption, we expected to find earlier gender mismatch effects for cataphora sentences as compared to anaphora sentences.

## 4.2 EEG Experiment 2 & 3: Anaphora vs. Cataphora

### 4.2.1 Materials & Method

***Participants Experiment 2: Anaphora.*** We tested twenty-four native speakers of English from the Glasgow University community who were all recruited from the University of Glasgow subject pool and paid for their participation (£6 per hour, depending on the duration between £15-£18). All subjects had normal or corrected to normal vision, normal auditory acuity (self-report), and no history of neurological or speech-language impairments. Prior to the experiment participants read an EEG study

information sheet and signed an informed consent form. Four participants were excluded because of high rate of artefact rejection. Among the remaining participants were 11 female and 9 males (mean age = 21.5).

*Materials Experiment 2: Anaphora.* The materials were based on the ones used in Kreiner et. al (2008). Experiment 2 used 160 anaphora sentences such as [13a–13d] where an antecedent noun preceded either a matching or mismatching co-referring, gender-marked reflexive (*himself / herself*; pronoun and role noun are both underlined in the examples), which represents the target word in the sentence. Each item had four versions, representing the four experimental conditions of a 2x2 design manipulating *Gender Type* (lexical [13a, 13b] versus stereotypical [13c, 13d]) and *Matching* (match [13a, 13c] versus mismatch [13b, 13d]). The selection of stereotypical role nouns was based on a norming study with 50 participants from Glasgow University who did not take part in the other experiments.

| |
|---|
| [13a] The <u>king</u> left London after reminding <u>himself</u> about the letter. |
| [13b] The <u>king</u> left London after reminding <u>herself</u> about the letter. |
| [13c] The <u>minister</u> left London after reminding <u>himself</u> about the letter. |
| [13d] The <u>minister</u> left London after reminding <u>herself</u> about the letter. |

*Participants Experiment 3: Cataphora.* 24 members of the Glasgow University community who had not taken part in the Anaphora experiment participated in this experiment. All were native English speakers with normal or corrected-to-normal vision and had not been diagnosed with any reading disorder. Each participant was paid a standard rate of £6 per hour. Four participants were excluded because of an extensively high rate of artefact rejection. Of the remaining 20 participant, 13 were female and 7 male (mean age = 23.5).

***Materials Experiment 3: Cataphora.*** Experiment 3 used 160 cataphora sentences such as [14a–14d], which were derived from the materials used in Experiment 2. The linear order of pronoun and noun was reversed, i.e. the referring pronoun occurred *prior* to the antecedent noun. Consequently, the noun represents the target word to which ERP - as well as TFR - analysis is time-locked to.

As in Experiment 2, each item appeared in four versions, representing the four experimental conditions in a 2x2 factorial design crossing Gender type (lexical ([14a, 14b) vs. stereotypical ([14c, 14d])) and Matching (Match ([14a, 14c]) vs. Mismatch ([14b, 14d])).

| |
|---|
| [14a] After reminding <u>himself</u> about the letter, the <u>king</u> left London. |
| [14b] After reminding <u>herself</u> about the letter, the <u>king</u> left London. |
| [14c] After reminding <u>himself</u> about the letter, the <u>minister</u> left London. |
| [14d] After reminding <u>herself</u> about the letter, the <u>minister</u> left London. |

## 4.3 Procedure: Anaphora & Cataphora

EEG was recorded while participants read silently sentences presented word-by-word on a computer screen. EEG signal was collected with a BIOSEMI Active-Two amplifier system from 72 scalp sites using Ag/AgCl electrodes mounted on an elastic cap (EASYCAP, Herrsching-Breitbrunn, Germany). EEG electrodes were placed following the extended 10–20 position system and two additional electrodes (Common Mode Sense [CMS] active electrode and Driven Right Leg [DRL] passive electrode) were used as reference and ground electrodes. EEG and EOG (eye blinks and eye movements) activity were sampled at 512Hz. Two non-standard positions per hemisphere (left: PO9', O9', right: PO10', O10') where located 33% and 66% off the M1-Iz / M2-Iz midline (an illustration of the channel layout can be found in Appendix A.2). The standard reference electrode was the left mastoid, however the data files were offline re-referenced to an

average reference (see Nunez and Srinivasan (2006) for discussion of different re-referencing schemes).

To render the experimental items less obvious, each trial was presented in a "short story" fashion, starting with a sentence title (varying between 2–5 words) presented on the screen until the participant was ready and pressed a key to continue. This was followed by a 500ms blank screen and then by a fixation cross in the center of the screen. Each word appeared in the center of the screen for a duration of 300ms, and with an inter-stimulus interval of 200ms. In addition to the 160 experimental items 160 filler sentences were included in each experiment. 25% of the stimuli (both experimental and fillers) were followed by a simple comprehension question that required a yes/no reply via button press.

## 4.4 Data Preprocessing: Anaphora & Cataphora

Trials containing blinks were corrected using the adaptive artifact correction method of Brain Electromagnetic Source Analysis (BESA) software (Ille, Berg, & Scherg, 2002). Automatic artifact detection software (BESA version 5.2) was applied on the data and trials with non-ocular artifacts (drifts, channel blockings, EEG activity exceeding ±75 μV) were discarded. To pertain an acceptable signal-to-noise ratio, participants for whom more than 12.5% of the trials of a particular experimental condition were rejected were excluded from the analysis (all together 4 participants in each experiment). Following this procedure, the data files were offline re-referenced to the average of the 72 electrodes and exported to Fieldtrip® for further pre-processing, and for the consecutive statistical analysis (see also chapter 2).

To account for filter artifacts, data-files starting 6s before critical word onset (the reflexive in the anaphora experiment, the antecedent noun in the cataphora experiment) and ending 6s after stimulus onset were exported. For the ERP analysis, a bandpass-filter of 0.3-30Hz was applied and the data were normalised on the single-trial relative to a 500ms pre-stimulus baseline interval preceding the critical word and using the electrodes' average as reference. By contrast to that, for the TFR analysis the data were de-trended and filtered using a dft-filter to remove line noise. After conducting the frequency analysis, the data were averaged over trials per subject and condition and baseline-corrected relative to a 500ms pre-stimulus baseline interval.

After pre-processing, the time-windows of interest were cut from the preprocessed long data-files. EEG was time-locked to the onset of the target word (i.e., the reflexive in Experiment 2 (anaphora) and the co-referring noun in Experiment 3 (cataphora)), and all analysis was conducted in a latency window starting with the onset of the critical word until 1000ms after.

## 4.5 ERP Analysis

For the statistical analysis of the ERP-effects as a function of experimental condition, we used an adapted version of the randomisation procedure proposed by Maris (2004; Maris & Oostenfeld, 2007; see also Experiment 1), with a cluster growing approach that corrects for multiple comparisons. The time-locked analysis using a permutation-based framework by means of cluster randomisation (Montecarlo simulation) as implemented in Fieldtrip® did not involve any restrictions or assumptions about time intervals and electrode sites, so in this sense we refer to it as the data-driven analysis approach. For the average potential in a certain time window (0-1000ms, where 0 represents the onset of the critical word), the clustering and randomisation test first computes a difference statistic between conditions, which is thresholded and clustered for observations in neighboring electrodes. A cluster-level statistic (i.e. the sum of *t*-

statistic) is computed for the samples in this joint set of (channel x time)-pairs. The maximum is taken from this set, and a *p*-value is calculated using Monte Carlo resampling in the randomisation test. The resulting contrast values for the ERP measures were taken as the average effect over the electrodes within the significant clusters.

However, we did not calculate all possible contrasts but focused instead on the main comparison between mismatch and match - separately for the lexical and the stereotypical conditions in each of the two experiments (anaphora and cataphora, respectively). Over the past years there have been various threads on the Fieldtrip mailing list regarding the possibility to test for interactions using a permutation test. Strictly speaking this is statistically not possible this way. The permutation-framework tests the null-hypothesis of exchangeability of data across allocated conditions, whereas when one wants to test for an interaction effect, one tests for a particular linear (parametric) model of the dependent variables explaining variance in the dependent variable. Inferring that exchangeability across conditions is unlikely, i.e. obtaining a small p-value through permutation, does not necessarily lead to the conclusion that there is an actual interaction effect. In the following we will describe the results of each analysis type (ERP, TFR, and Source Analysis) for the anaphora and the cataphora experiment together, as it makes it easier to compare shared and differential effects between the two experiments.

## 4.6 ERP results: Anaphora

*Lexical conditions: Mismatch vs. Match*. We first compared the mismatching to the matching conditions for the lexical stimuli. We observed a negative cluster (i.e. stronger negativity in the mismatch than in the match condition) that started at 260ms after the onset of the critical pronoun, but reached is largest extension across electrodes around 400ms (see Fig. 13). This effect seems to reflect the anticipated differences in

terms of an N400 component, which is more pronounced over centro-parietal areas over the right hemisphere (p= 0.024 (*), time = 0.26 to 0.46). This appears to be in line with earlier research that has shown that the scalp distribution of the N400 is strongest over centro-parietal areas and, at least for written input, appears to be larger over the right hemisphere (for the complete grandaverage plots, please refer to Appendix C.).
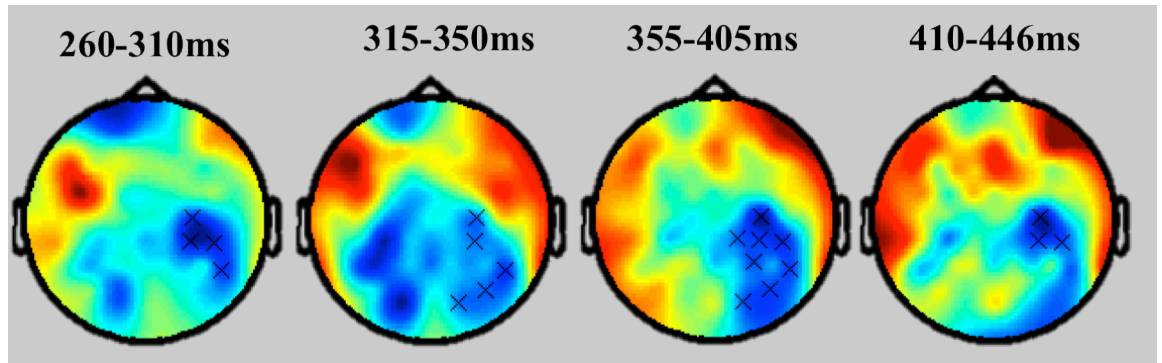


*Figure 13: Anaphora lexical conditions: Statistical map of the N400-like effect for the difference between lexical mismatch minus match in the Anaphora experiment. Topographical plots are shown for the statistical significant time-window 260ms – 460ms (top to bottom) after stimulus-onset (the reflexive). Significant time\*electrode-clusters are highlighted with 'x'.*

Starting at around 550ms a positive cluster emerges with a very different topography that carries on up to the end of the sentence around 1000ms (see Fig. 14 below). At its peak the topography of this positivity seems to include symmetrical electrode clusters over centro-parietal sites of both hemispheres (positive cluster, p-value: 0.005 (*), time = 0.54688 to 1s) as well as an anterior negative cluster that could either be the negative complement of a dipolar patterns or it could reflect an additional processing difference in anterior parts of the brain (negative cluster, p= 0.001 (*), time = 0.55469 to 1). The predominantly positive signature, the timing, and topography of this effect make it compatible with the interpretation as a P600 component, which is also congruent with the initial predictions for this particular manipulation. I will discuss these results in more detail in section 3.5.
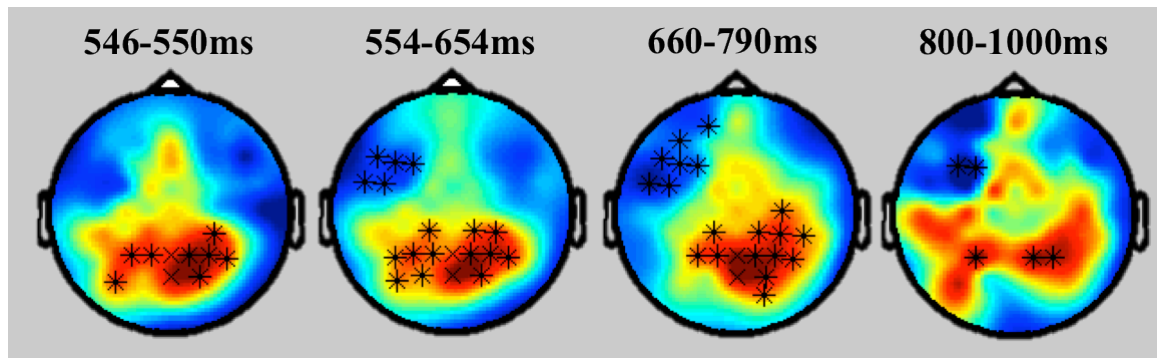
*Figure 14: Anaphora lexical conditions: Statistical map of the P600-like effect, which is accompanied by an anterior negativity (AN) in the same time-window for the difference between lexical mismatch minus match in the Anaphora experiment. Topographical plots are shown for the statistical significant time-window 550ms – 1000ms (top to bottom) after stimulus-onset (the reflexive). Significant time\*electrode-clusters are highlighted with '\*' and 'x'.*

***Stereotypical conditions: Mismatch vs. Match***. The contrast mismatch vs. match for the stereotypical stimuli revealed a very similar late component but an absence of the difference around 400ms as can be seen in Fig. 15. In fact a left lateral posterior positivity is observed quite early around 450ms. This effect slightly changes topography over time by moving more centrally and resulting in a similar topography as for the lexical stimuli (see Fig. 13). Again this late positivity is compatible with a P600 component, but seems to be shorter-lived than in the lexical case, ending around 800ms after stimulus onset (reflected in two positive clusters: positive cluster 1: p= 0.01 (\*), time = 0.47 to 0.8s; positive cluster: 2, p = 0.006 (\*), time = 0.53 to 0.76s). Analogous to the ERP effects in the lexical manipulation, the P600 effect co-occurs with a late left-lateralized anterior negativity (AN), which persists slightly longer than the P600 effect (negative cluster: 1, p= 0.003 (\*), time = 0.49 to 0.83s; for the complete grandaverage plots, please refer to Appendix C.)
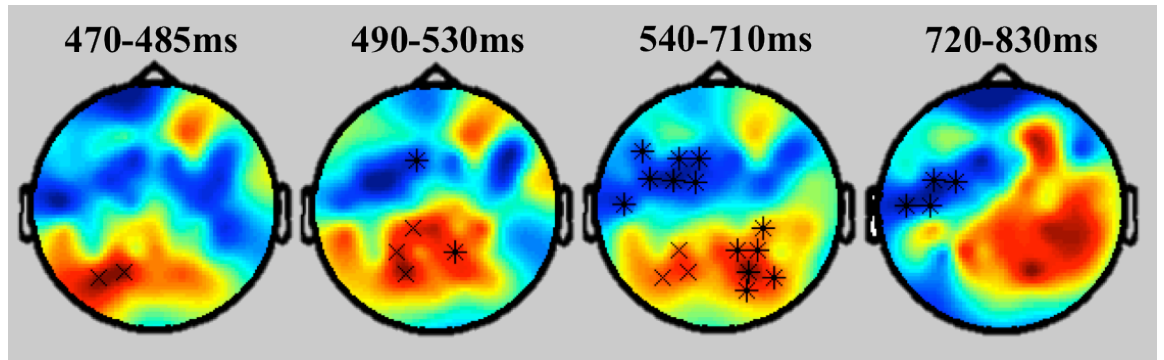
*Figure 15: Anaphora stereotypical conditions: Statistical map of the P600 effect, which is accompanied by an anterior negativity (AN) in the same time-window for the difference between stereotypical mismatch minus match in the Anaphora experiment. Topographical plots are shown for the statistical significant time-window 470ms – 830ms after stimulus-onset (the reflexive). Significant time\*electrode-clusters are highlighted with '\*' and 'x'.*

## 4.7 ERP Results: Cataphora

***Lexical conditions: Mismatch vs. Match***. While lexical and stereotypical stimuli reveal systematic differences (N400 effect) and communalities (AN and P600 effects) in the anaphora experiment, the picture is very different for the cataphora. Here lexical and stereotypical stimuli seem to induce very different processes across the entire trial period (from the onset of the critical word up to 1000ms after). Lexical stimuli induce a left anterior negativity (LAN) (mismatch more negative than match) that onsets at 320ms and dies down around 630ms (Fig. 16; Negative cluster: 1, p= 0.021 (*), time = 0.32 to 0.63s).
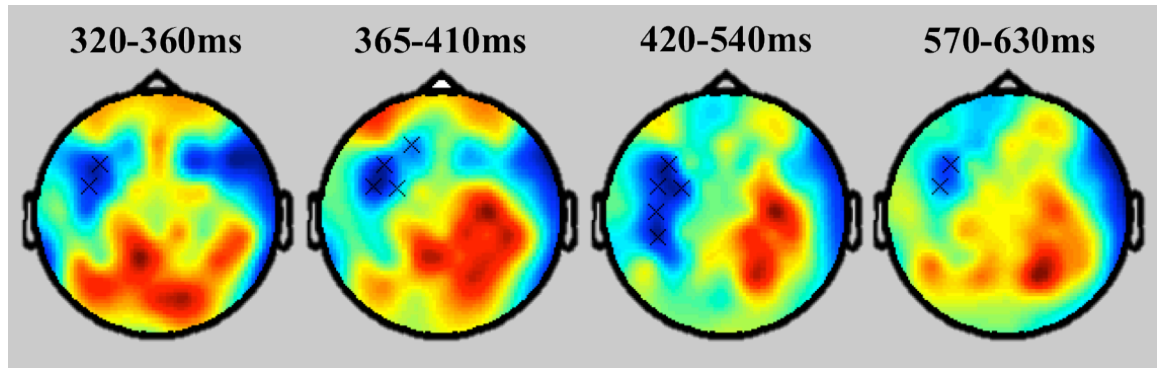
*Figure 16: Cataphora lexical conditions: Statistical map of the LAN effect for the difference between lexical mismatch minus match in the Cataphora experiment. Topographical plots are shown for the statistical significant time-window 320ms – 630ms (top to bottom) after stimulus-onset (the noun). Significant time\*electrode-clusters are highlighted with 'x'.*

***Stereotypical conditions: Mismatch vs. Match***. By contrast, the stereotypical stimuli induce a shorter-lived posterior positivity that starts 225ms after onset of the critical noun and last until 445ms after stimulus-onset (Figure 17). This positivity appears over centro-parietal electrode sites with bilateral distribution (represented by 2 positive clusters: positive cluster: 1, p= 0.042 (\*), time = 0.25 to 0.33; positive cluster: 2, p= 0.045 (\*), time = 0.23 to 0.45). This effect may represent a P300 effect, a positive going ERP component peaking around 300ms after stimulus onset. The P300 has been has been shown to be sensitive to the processing of unexpected events in a wide variety of types (e.g., Duncan-Johnson & Donchin, 1977; Ruchkin, Sutton, & Tueting, 1975). More precisely, the P300 is an ERP component in response to improbable stimuli and is influenced by the subjective probability that a particular stimulus will occur. The P300 has been closely linked to context updating, which can be triggered by unexpected stimuli (Donchin, E., & Coles, M. G. H., 1988). Overall, mismatch-match differences in the cataphora experiment are much earlier and shorter-lived, which may be indicative for predictive processing mechanisms (Federmeier et al., 2007), and reveal qualitatively distinct components between lexical and stereotypical stimuli (for the complete grandaverage plots, please refer to Appendix C.).
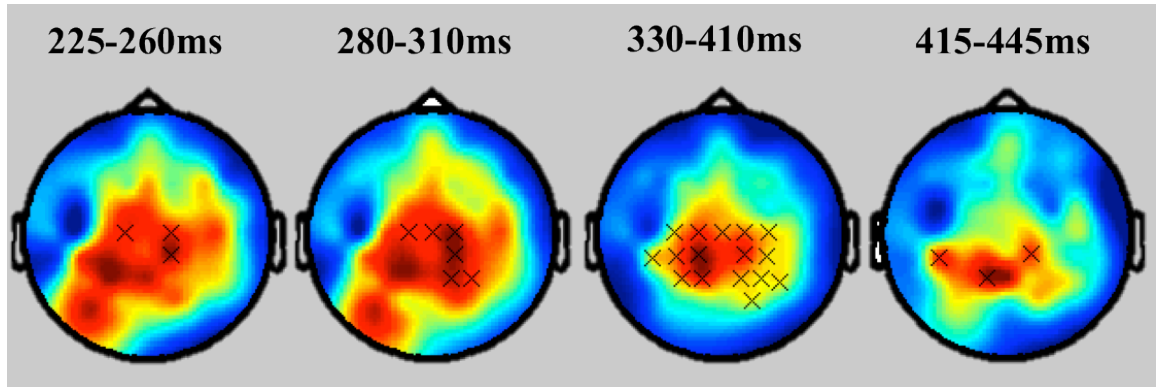
*Figure 17: Cataphora stereotypical conditions: Statistical map of the P300 effect for the difference between stereotypical mismatch minus match in the Cataphora experiment. Topographical plots are shown for the statistical significant time-window 225ms – 445ms (top to bottom) after stimulus-onset (the noun). Significant time\*electrode-clusters are highlighted with 'x'.*

## 4.8 Oscillatory effects: Anaphora & Cataphora

***TFR analysis.*** To localize the areas involved in the processing of a gender-mismatch in anaphoric and cataphoric contexts, we determined a time–frequency signature in response to conflict processing by calculating time–frequency representations (TFRs) for each item, condition, and each subject, time-locked to the presentation of the critical word (the reflexive in anaphora sentences, the antecedent noun in the cataphora experiment). TFRs were computed on single trials in the frequency range of 1–80 Hz at 50 geometrically sampled frequencies by using morlet wavelets (multitaper approach). The TFRs were normalized for each frequency by subtracting the mean baseline value and dividing by the baseline standard deviation. The baseline was defined as the 200ms preceding the onset of the critical word. The strongest conflict-related activity was seen in the theta band (4–7 Hz) for the anaphora experiment for both, lexical and stereotypical conditions. By contrast, the cataphora experiment not only showed a power increase in the theta frequency band (stereotypical conditions), but also a strong power decrease in the alpha frequency range (8-12Hz) in the lexical conditions.

Subsequently, we optimized the analysis for those frequency bands with the strongest effects, ensuring at least 5 cycles for the lower frequencies and using a single Hanning-taper with 1Hz resolution for the theta and alpha frequency bands individually. Then, the frequency grand average over all subjects was calculated for each condition separately. We contrasted the mismatching conditions (of each noun type) with their corresponding matching control condition by calculating the percent change between mismatch and match. This was done by subtracting the global power of the matching control from its mismatching counterpart and dividing the result with the power of the matching condition. The significance of the difference between the mismatching condition and the control (time-locked with the critical word respectively) was determined by means of a nonparametric randomisation test implemented as Cluster Randomisation Analysis in the Fieldtrip toolbox (Maris & Oostenveld, 2007). This test effectively accounts for the multiple comparison problem (such as 72 channels and multiple time-points) by computing two-sided t-tests (p = 5%) for the difference between the conditions for neighboring (channel x frequency x time) - pairs (TFR analysis). Next, the neighboring channels of channel-time-frequency pairs that exhibit the same direction of effect are clustered. The cluster with the maximum sum is used as the cluster-level test statistic under the randomisation null distribution. The randomisation null distribution was obtained by randomizing the order of the grandaverage data of the relevant conditions within every participant. This reference distribution of cluster-level t statistics was created from 1000 randomisations. The p-value was estimated according to the proportion of the randomisation null distribution exceeding the observed maximum cluster-level test statistic (the MonteCarlo p-value). By creating 1000 random draws, this Monte Carlo p-value is an accurate estimate of the true p-value.

***TFR analysis: Anaphora lexical conditions.*** For anaphora, the gender-mismatch in the lexical conditions elicited a statistically significant early increase in theta activity (4-7Hz) in the right frontal lobe over midline and right frontal electrode sites starting 80ms after stimulus onset and lasting until 960ms after it (positive cluster: 1, p= 0.009 (*), time = 0.08 to 0.96). This was followed by a by a posterior power increase bilaterally over parietal electrodes starting around 190ms after stimulus onset until 800ms after stimulus onset (positive cluster: 2, p= 0.026 (*), time = 0.19 to 0.8).

Figure 18 illustrates the statistical significant output of the cluster randomisation analysis (Maris et al., 2007) for the theta power increase effects on the channel (or electrode) level. Figure 19 shows the mean raw effect of the theta power increase at representative frontal (Fz, F2, F4) and left parietal (CP3, CP1, P1, P3).
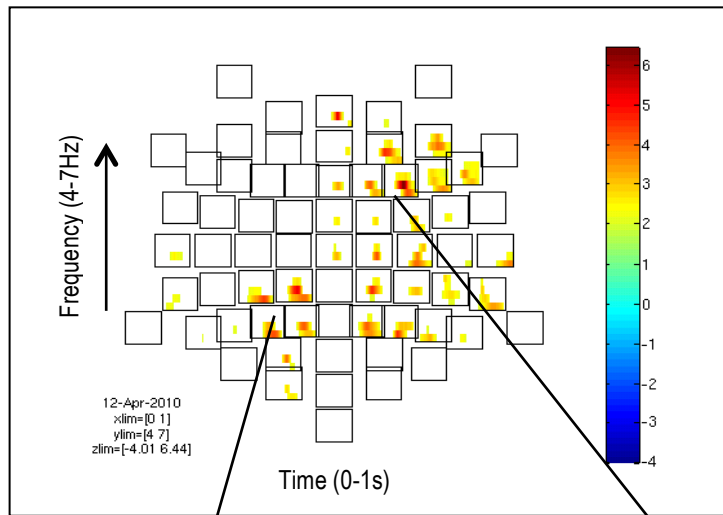
*Figure 18: Anaphora lexical conditions: Surface effect at the channel level showing an increase of theta activity for lexical mismatch compared to lexical match (king→herself) involving a network of right lateral prefrontal and bilateral parietal areas.*
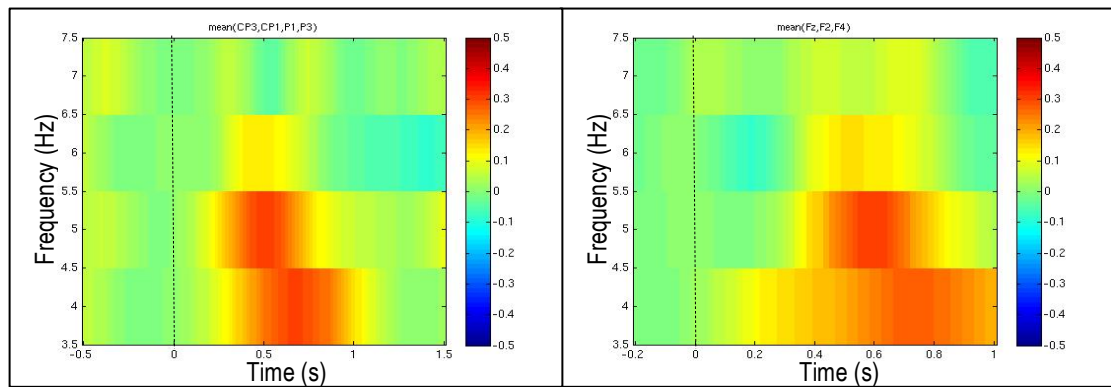


*Figure 19: Mean raw effect at representative left parietal (left) and right frontal-midline electrodes (right) for the theta power increase (4-7Hz) for the lexical condition contrast in the anaphora experiment. Regions with warmer (red) colours indicate a power increase relative to baseline; regions with cooler (blue) colour reflect a power decrease.*

***TFR analysis: Anaphora stereotypical conditions.*** Much the same as with the lexical conditions, the stereotypical conditions induced a strong increase of theta power over frontal midline electrodes which was followed by a weak increase over right temporal and parietal electrodes (as reflected in two positive clusters; positive cluster: 1, p= 0.009 (*), time = 0.08 to 0.96; positive cluster: 2, p= 0.026 (*), time = 0.2 to 0.8). This frontal-midline effect started around 80ms after critical word onset and extended to 960ms after it while the right temporal / parietal cluster occurred in a latency of 200ms to 800ms after critical word onset. As expected, the stereotypical gender mismatch effect was not as strong and not as distributed as the gender mismatch effect observed in the lexical condition contrast.

Figure 20 illustrates the statistical significant output of the cluster randomisation analysis for the theta power increase effects on the channel level. Figure 21 depicts the mean raw effect of the theta power increase at representative frontal (F1, Fz, F2, FCz) and left parietal (C6, T8, TP8) electrodes.

*Figure 21: Mean raw effect at representative frontal-midline (left) and right temporal / parietal electrodes (right) for the theta power increase (4-7Hz) for the stereotypical condition contrast in the anaphora experiment. Regions with warmer (red) colours indicate a power increase relative to baseline; regions with cooler (blue) colour reflect a power decrease.*

***TFR analysis: Cataphora lexical conditions.*** Contrary to the effects for the lexical gender mismatch effect in the anaphora experiment, we did not observe effects in the theta frequency range, but in the alpha frequency range (8-12Hz). The cluster randomisation revealed a decrease in alpha power for the mismatch compared to the matching conditions over left temporal / parietal and right temporal / parietal electrode sites almost immediately after the critical word onset (as reflected in two negative clusters; Negative cluster: 1, p= 0.021 (*), time = 0.06 to 0.7; Negative cluster: 2, p= 0.022 (*), time = 0 to 0.76). The left temporal cluster started 60ms after stimulus onset and lasted until 700ms after stimulus onset. The right temporal cluster, which extended to parietal regions, occurred in a latency range from 0ms (stimulus onset) until 760ms, but was not as pronounced as the left temporal cluster.

Figure 22 depicts the statistical significant output of the cluster randomisation analysis for the alpha power decrease on the channel level. Figure 23 shows the mean raw effect of the alpha power decrease at representative left temporal / parietal (T7, CP5, P5, P7) and right temporal / parietal (C2, CP4, CP2, P8) channel sites.
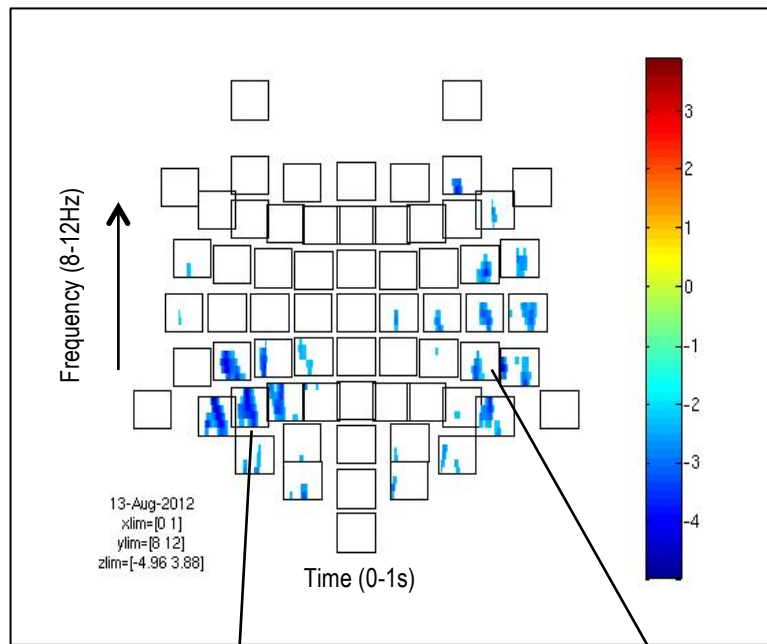
*Figure 22: Surface effect at the channel level showing a decrease of alpha activity for lexical mismatch compared to lexical match (herself --> king) involving mostly left temporal electrodes as well as right temporal / parietal electrode sites.*
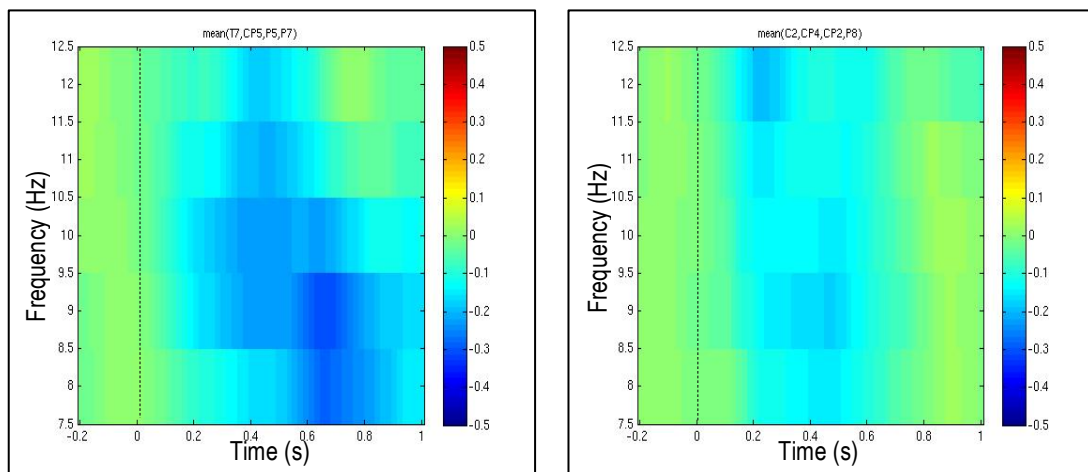


*Figure 23: Mean raw effect at representative left temporal (left) and right temporal / parietal electrodes (right) for the alpha power decrease (8-12Hz) for the lexical condition contrast in the cataphora experiment. Regions with cooler (blue) colour reflect a power decrease as compared to baseline.*

*TFR analysis: Cataphora stereotypical conditions.* Similar to the lexical gender mismatch effect in the cataphora sentences, we found induced activity also over posterior brain areas. However, this effect was represented by an early increase of theta power (4-7Hz) over left-lateral parietal brain areas (1 positive cluster; p = 0.04 (*), time = 0 to 0.5). Figure 24 illustrates the statistical significant output of the cluster randomisation analysis for the theta power increase on the channel level. Figure 25 shows the mean raw effect of the theta power increase at representative left parietal (TP7, CP5, P3, P5) channel sites.
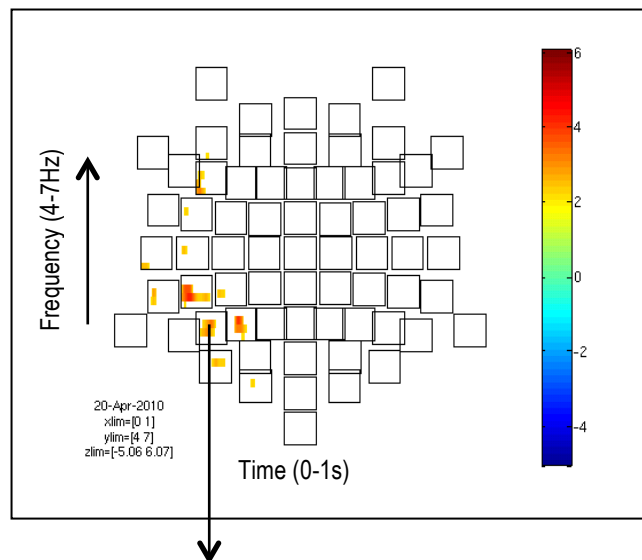


*Figure 24: Surface effect at the channel level showing an increase of theta power for stereotypical mismatch compared to stereotypical match (herself --> minister) involving mostly left parietal electrode sites.*
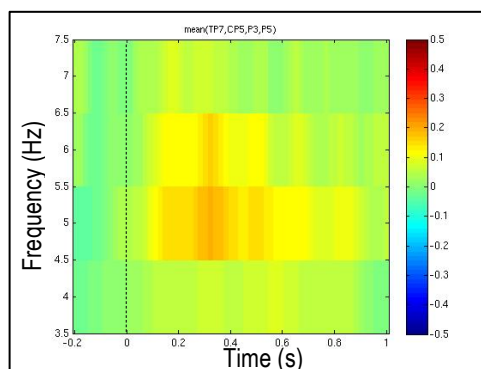


*Figure 25: Mean raw effect at representative left parietal electrodes for the theta power decrease (4-7Hz) for the stereotypical condition contrast in the cataphora experiment. Regions with warmer (red) colours indicate a power increase relative to baseline*

### 4.9 Source Analysis: Anaphora & Cataphora

Subsequent source analysis was focused on the wavelet transform centered at 4 Hz for the theta activity in the anaphora and cataphora experiment by using a morlet wavelet. For the alpha activity decrease in the cataphora experiment a center frequency of 9Hz was chosen for the left lateral cluster, while the analysis for the right lateral cluster was centered around 11Hz. The wavelet transform was used to compute the cross-spectral density of all combinations of channels in the chosen time–frequency area, allowing the dynamic imaging of coherent sources (DICS) (Gross, 2006) localization for all 20 subjects for each experiment separately. DICS uses spatial filters in the frequency domain to create tomographic functional maps based on power that are displayed on either individual anatomic MRimages, or, as it was done here, on a standard BEM MRimage using SPM2 (http://www.fil.ion.ucl.ac.uk/spm/software/spm2; for a detailed description of this method see Experiment 1, chapter 3.4.8).

The beamforming approach localized the gender-mismatch for the lexical conditions (*Figure 26*) in the right IFG (BA 46) and for the stereotypical conditions (*Figure 27*) in the ACC (BA 32).
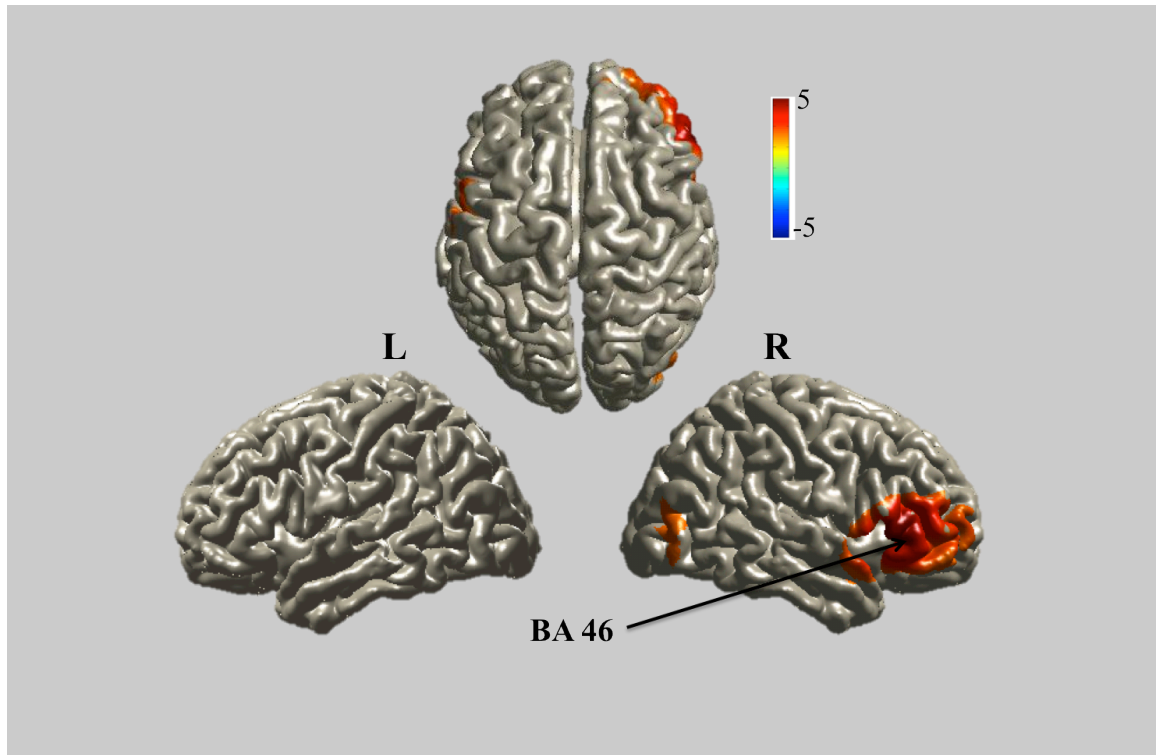
*Figure 26: Anaphora: lexical conditions (king -> herself; mismatch - match): surface projection of the statistical significant increase in theta activity (4-7Hz) Maximum Activity: right inferior Frontal Gyrus (BA 46)*
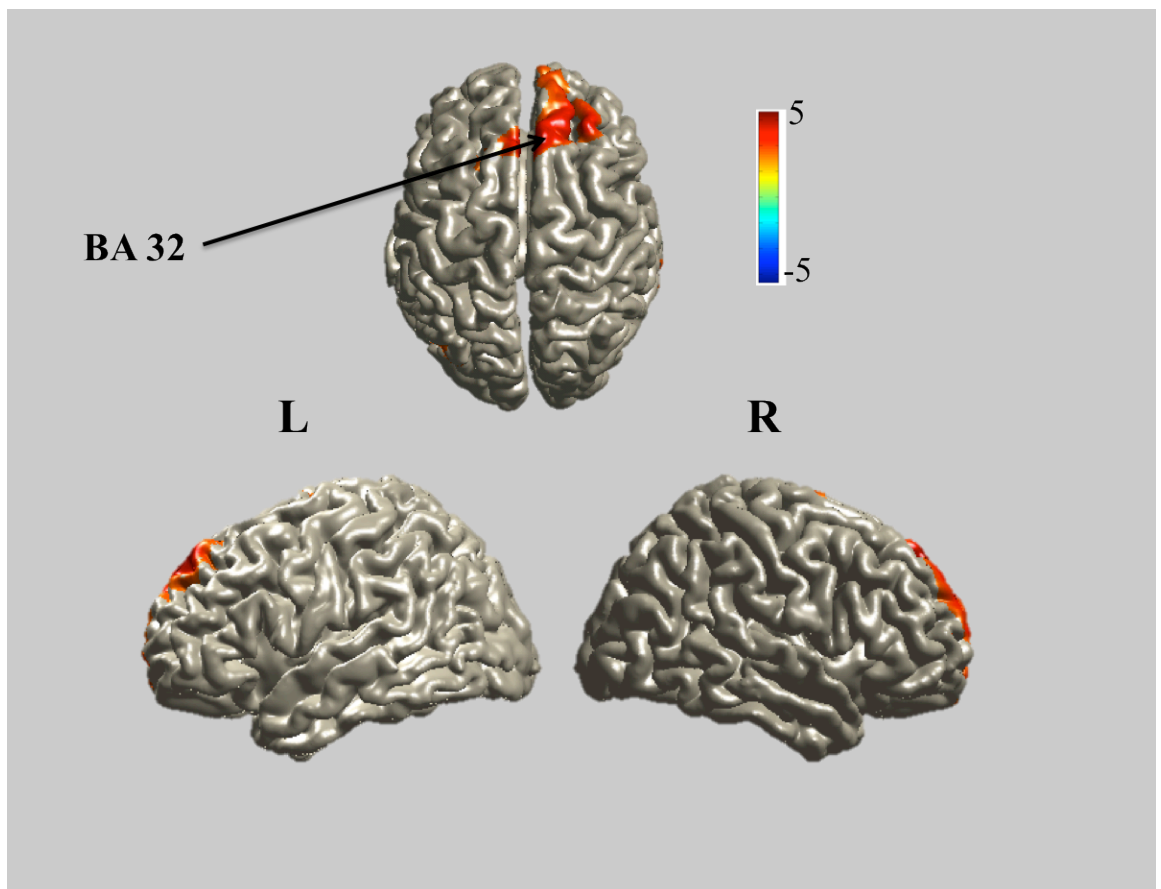


*Figure 27: Anaphora: stereotypical conditions (minister -> herself); Surface projection of the statistical significant sources for the increase of frontal-midline theta activity (4-7Hz); Maximum Activity: Cingulate gyrus, ACC (BA 32) -> activation of domain-general executive functions,*

By contrast, cataphora processing engaged posterior brain areas which are typically associated with language processing: a bilateral decrease of alpha activity for the lexical conditions (Figure 28, Figure 29), localized in the middle temporal gyrus (BA 21), represented by two negative clusters, engaging first parietal / temporal areas of the left hemisphere (p = 0.02, time = 0.03 to 0.69s), which extended to parietal areas (BA 39/40; see Figure 29) of the right hemisphere (p = 0.02, time = 0 to 0.76s).
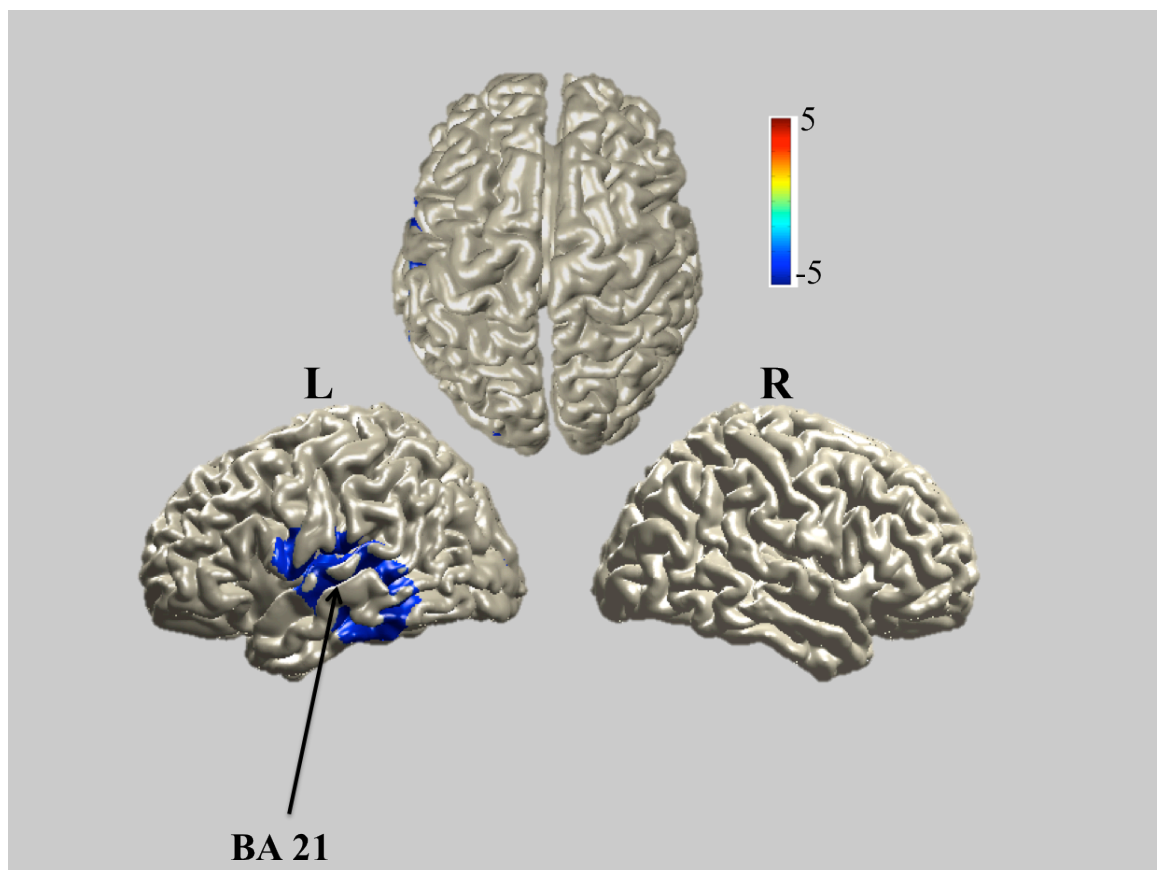


*Figure 28: Cataphora: lexical conditions (herself -> king); Left: Statistical significant decrease of alpha activity (8-12Hz) on the sensor level; Middle and Right: Activation maps on the source level for the left-lateral cluster. Maximum Activity: Middle Temporal Gyrus (BA 21, word-form processing, lexical-semantic access) -> Attempt to resolve linguistic conflict using domain-specific processes; Decrease in alpha activity = intense processing, attentional networks. This possibly reflects lexical-semantic access and increased working-memory load (Roehm et al. 2001), because the clash of the lexical noun with its preceding mismatching pronoun cannot be resolved.*
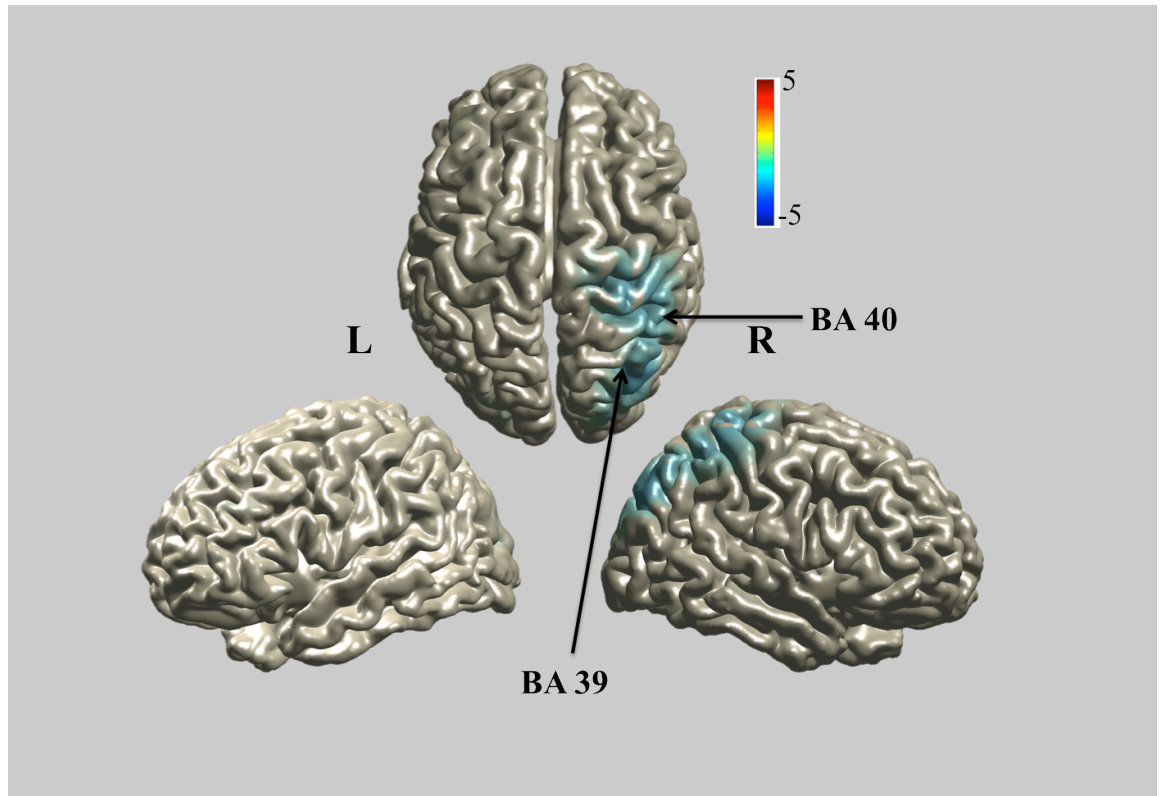
*Figure 29: Cataphora: lexical conditions (herself -> king); Statistical significant decrease of alpha activity (8-12Hz) for the late negative cluster projected on a surface brain; Maximum Activity: right parietal lobe (BA 39/40),*

For the stereotypical conditions (Figure 30) a left-lateralized temporal increase in theta activity (BA 40) was observed in an early time window ($p = 0.05$, time = 0 to 0.5s). At the same time, we observed activation in left medial/superior occipital gyrus (BA 18), most likely in response to the visual word form processing. Taken together these results show a qualitative difference in linguistic conflict resolution: in anaphora it is assisted by domain-general cognitive systems whereas in cataphora it is resolved within language-specific cognitive systems in a more automatised fashion. We suggest that the posterior activation reflects domain-specific linguistic processes within encapsulated linguistic networks. Interestingly, the left hemisphere is also associated with predictive language processing strategies (Federmeier, 2007), implying that the parser makes assumptions about the gender of the incoming noun. Upon encountering an unpredicted stereotypical

noun (which is biased towards a certain gender), the reader is able to overwrite or repair its initial interpretation by assigning an unpreferred yet plausible antecedent.
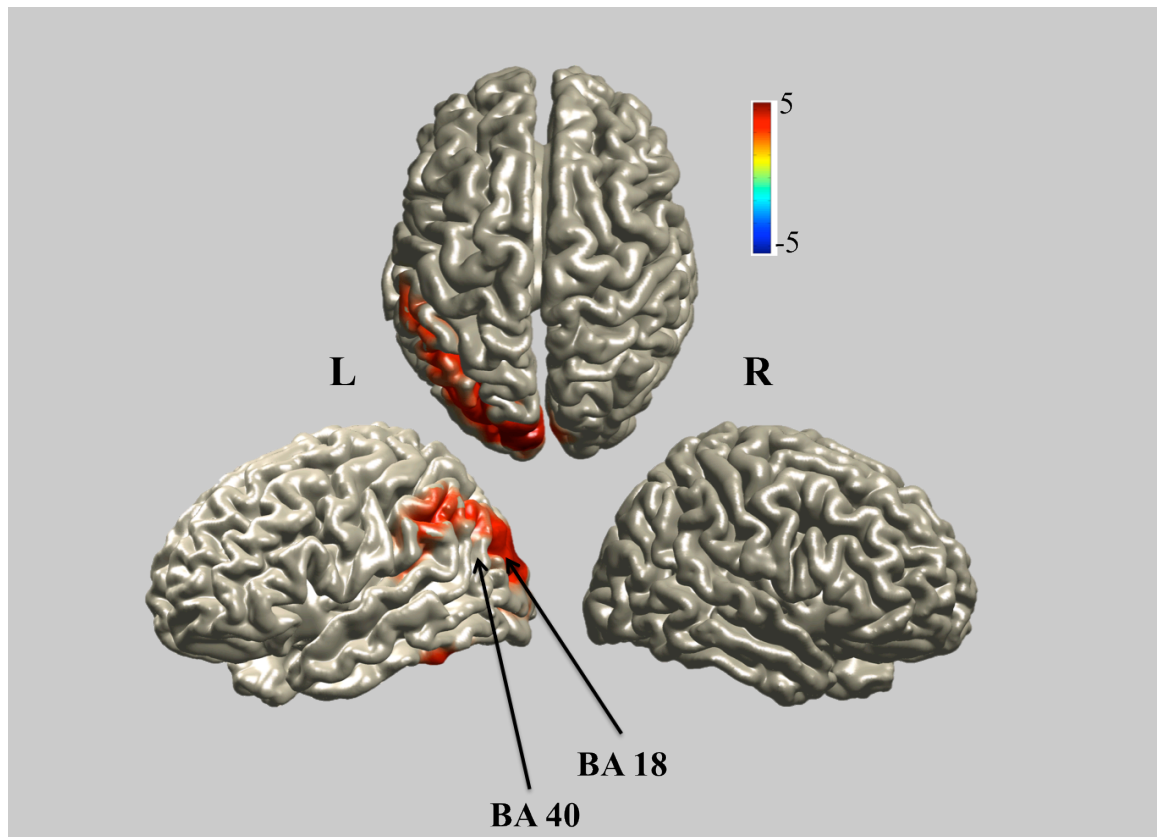


*Figure 30: Cataphora: stereotypical conditions (herself -> minister): Activation maps on the source level. Maximum Activity: Left inferior parietal lobe (BA 40), which is typically involved in reading (both in regard of phonology and meaning)*

**4.10 Summary & Discussion: Anaphora & Cataphora**

In line with our hypotheses, we found distinct activation patterns between the two experiments when confronted with conflicting gender information, in terms of ERP component, oscillatory components, and source localization:

**4.10.1 ERP results**

The ERP results for the anaphora experiment generally replicate Osterhout et al.'s (1997a) finding that violations of gender agreement in anaphora sentences result in P600 like components, regardless of the noun type. While Osterhout and colleagues reported differences between lexical and stereotypical gender in amplitude only, the data-driven analysis conducted here revealed distinct time-course patterns between the processing of agreement mismatches for lexical compared to stereotypical gender: A similar centro-parietal positive cluster revealing the expected P600 component was shown for lexical and stereotypical nouns equally. This is also consistent with previous eye-tracking results that showed that agreement violations in anaphora sentences for both noun-types result in reading difficulty (Kreiner et al, 2008). However, contrary to Osterhout's results, we observed a negative component that preceded the P600 component for the lexical gender mismatches only. As the negative component had the typical latency (300-500ms) and topography (centro-parietal), we refer to this component as N400 effect.

Interestingly, the P600-effects for both noun types co-occur with a left anterior negativity effect (LAN). Although the LAN is usually found in a latency range of 300ms – 500ms after stimulus onset, there have also been numerous reports of anterior negativities appearing in later time-windows: these anterior negativities have been shown to be evoked by morphosyntactic violations such as number agreement, verb inflection violations, and most importantly here, gender agreement violations (Gross, Say, Kleingers, Clahsen, & Münte, 1998; Gunter, Friederici, & Schriefers, 2000; Hahne & Jescheniak, 2001; Vos, Gunter, Kolk, & Mulder, 2001, see Vos, 2001 for review on anterior negativities). Another strand of research relates anterior negativities that are elicited by grammatical violations to some aspects of working memory operations, namely, working memory load (Kluender & Kutas, 1993a, 1993b). Studies supporting this view have reported anterior negativities for grammatically well-formed sentences in

which an increased demand of working memory resources was supposed to take place (King & Kutas, 1995; Kluender & Kutas, 1993a; Weckerly & Kutas, 1999). Additional evidence for the claim that anterior negativities may be reflecting working memory operations stems from the findings that the amplitude of the left anterior negativity elicited by morphosyntactic violations was modulated by the working memory span of the subjects (as classified according to the Reading Span Test) (Daneman & Carpenter,1980). Similarly, the presence of a concurrent working memory load task affected the amplitude of the LAN effect (e.g., Vos et al., 2001).

In the cataphora experiment, we also observed distinct component for the two noun types: Gender agreement mismatches in the lexical conditions resulted in a left anterior negativity (LAN), while gender agreement mismatches in the stereotypical conditions elicited an early, centro-parietal positivity in the classical time window of the P300 component. The LAN has been elicited by a various (morpho-) syntactic violations, such as agreement violations (Coulson et al. 1998, Gunter et al. 1997, Münte et al. 1997, Kaan 2002, Osterhout and Mobley 1995), case violations (Münte and Heinze 1994), phrase structure violations, (Friederici, Hahne, and Mecklinger 1996, Hagoort, Wassenaar, and Brown 2003), island constraint violations (Kluender and Kutas 1993b), and even garden-path sentences (Kaan and Swab 2003). Besides this, LAN-effects has also been found during the processing of long-distance dependencies such as wh-movement, at the displaced wh-word as well as the unambiguous cue for the gap location (Kluender and Kutas 1993a, Phillips, Kazanina, and Abada 2005). The P300 (or P3b) is a general response to unexpected stimuli and has also been related to context-updating (Coulson et al. 1998, see Osterhout and Hagoort 1999 for a response).

### 4.10.2 Oscillatory effects and source localization

Again, we found differential activation pattern for anaphora compared to cataphora: Similar to Bastiaansen et al. (2002b), gender agreement violations for both noun types elicited an increase in power in the theta frequency band (4-7Hz) over right-frontal and midline brain areas. As expected, the gender mismatch effect for the lexical conditions appears to be stronger, activating large scale networks of prefrontal and parietal regions, reflecting the interplay between controlled mechanisms and local storage functions. Source analysis localized this effect in the right dorsolateral prefrontal cortex (BA 46), while the theta band effect for the stereotypical conditions localized in the ACC (BA 32). In line with our hypothesis, Bastiaansen (2002a) and Hald (2006) have also suggested that the frontal-midline theta increase can also be explained in terms of general error monitoring mechanisms.

By contrast, in the cataphora experiment we found oscillatory effects in two different frequency bands: The gender agreement mismatch in the lexical conditions resulted in a decrease of alpha activity (8-12Hz). This is likely to reflect more intense processing due to attentional processes when confronted with incongruent gender information. The local maximum for this effect as determined by the source analysis localized for the more pronounced cluster in the left temporal lobe (BA 21), while the less pronounced cluster localized in the right parietal cortex (BA 39/40). These regions represent linguistic-specific areas involved in lexical-semantic storage and word-form processing (e.g. Hagoort, 2005).

The stereotypical conditions revealed an increase in the theta frequency band (4-7Hz), which appeared almost instantly after stimulus onset over left parietal electrode sites, suggesting predictive processing strategies in the cataphora context for these noun types. The left hemisphere is associated with predictive language processing strategies (Federmeier, 2007), implying that the parser makes assumptions about the gender of the

incoming noun. Upon encountering an unpredicted stereotypical noun (which is biased towards a certain gender), the reader is able to overwrite or repair its initial interpretation by assigning an unpreferred yet plausible antecedent.

Again, the stereotypical mismatch effect was much weaker than the lexical gender mismatch as the conflict for the lexical conditions cannot be resolved. The local maximum for the theta effect in the stereotypical conditions localizes in the left inferior parietal cortex (BA 40). This region is assumed to be involved in reading, both in regard of phonology and meaning.

Let us recapitulate the matter of predictive processing: Predictions are typically made on the basis of expectations about which event is the most likely to occur and, depending on the specific scenario, are made with more or less certainty. We can relate this idea to the current experiments: Specific context-based forward predictions in cataphoric sentences trigger conflict-processing within encapsulated linguistic networks, while the uncertainty in anaphora sentences, i.e. in a less constraining context, leads to activation in domain-general prefrontal networks associated with controlled processing. Similarly the speed with which these effects are observed is quite striking. Following a similar argument to that of Lau et al. (2006), it is hard to imagine a gender mismatch effect taking place so early without prior prediction.

As Dehaene and colleagues suggest, automatisation usually leads to decreased activation in the dorsolateral prefrontal cortex and anterior cingulate cortex. Specifically, automatic processing increases activation in specialized processors, but does not require the coordination of global workspace neurons through large-scale networks. This fits nicely with the results observed for anaphora and cataphora when faced with conflicting gender agreement. In line with Cohen (2011) it seems that similar to Experiment 1 theta power increases in prefrontal brain regions are particular sensitive to controlled conflict processing.

# 5. MEG Experiment: The effect of cognitive load on syntactic Garden-Path processing (FIMS00745)

## 5.1 Introduction

One of the most studied topics in cognitive psychology is Working Memory (WM), which represents a system for actively maintaining and manipulation information. The most comprehensive model of working memory has been proposed by Baddeley in 1992. His model consists of two subsystems, the phonological loop and the visuospatial sketch pad, which are important for maintaining verbal and visual information. These systems are further divided into passive storage of information and active rehearsal processes. The central executive represents the core system to actively manipulate information in held in Working Memory. This framework is in one form or the other at the heart of many theories of human cognition.

Most sentence processing theories acknowledge the fact that working memory and working memory limitations play an important role regarding the fashion in which sentences are processed (e.g., Caplan & Waters, 1999; Chomsky & Miller, 1963; Gibson, 1991, 1998; Just & Carpenter, 1992; McDonald & Christiansen, 2002; Miller and Chomsky, 1963). This understanding led to much research investigating the processing of mostly unambiguous sentences and demonstrated that working memory factors including integration cost, storage cost, and memory interference heavily influence how sentence processing takes place. As a consequence, the processing of complex syntactic structures compared to the processing of less taxing sentences gives rise to locally increased neuronal activation. One of the factors that make the processing of some sentences more challenging than others are local ambiguities where syntactic cues allow multiple interpretations (as for instance locally ambiguous sentences such as syntactic garden-path sentences (see Experiment 1)). More precisely, in situations where local syntactic ambiguities arise, the human parsing mechanism is assumed to prefer the

structure that imposes the least memory load, leading to increased load when a less preferred interpretation has to be pursued. As reported for Experiment 1, the comparison between locally ambiguous reduced-relative clauses and their corresponding unambiguous control resulted in theta band enhancement in networks typically associated with increased working memory demands, namely the superior frontal gyrus (BA 6) and temporo-parietal brain regions.

By contrast, most research on structural complexity has largely focused on unambiguous sentences. Among those, some studies have investigated whether there are specific working memory resources exclusively dedicated to sentence processing or whether linguistic mechanisms share general resources, while others have developed models about the type of sentences that result in a high working memory load.

One of the most influential of these theories is Gibsons's dependency locality theory (DLT, also called Syntactic Prediction Locality Theory (SPLT); Gibson, 1998; 2000), which includes metrics based on memory cost and integration cost. According to the DLT, working memory resources are required 1) for storage of information about structural components that were already processed, and 2) for the integration of the current word into this structure. Typically, integration cost during sentence processing arises when discourse referents such as nouns and verbs have to be integrated into the current mental representation. Similarly, the number of new discourse referents that intervene between the first occurrence and the integration point determines the integration cost.

The current MEG experiment (12 participants, visual presentation) focuses on the analysis of event-related desynchronization and synchronization in the time-frequency domain of the MEG signals and is complemented by MEG data analysis in the amplitude-time domain. These techniques are employed here, using the findings from EEG experiment 1, 2, and 3 as an additional constraint for the source localization of the observed effects. MEG is an excellent method to tap into the dynamics of neural network

synchronization in response to the stimuli described below as it offers excellent temporal resolution combined with reasonable spatial resolution.

More precisely, the MEG experiment investigates the effects of cognitive load due to structural complexity on syntactic garden-path processing. To achieve this, we manipulated structural complexity using the main clause / reduced relative clause ambiguity (see Exp. 1). For the statistical analysis we employed the same methods as used for the previous experiments, including source localization of the event-related fields (lcmv beamforming technique) and oscillatory effects (DICS beamforming technique).

Many EEG as well as MEG studies have shown that event-related modulations evoked by syntactically complex sentences are often reflected in sustained anterior negativities (e.g. Federmeier et al, (2000)) late centro-parietal positivities (e.g. Kaan et al. (2000)), or even a combination of both. For instance, Fiebach et al (2001) investigated the processing of German wh-questions using EEG and observed a sustained anterior negativity which was followed by a late positive component. In line with Gibson's DLT they suggested that the sustained negativity reflects syntactic working memory costs that increase over time while the positivity might reflect increased integration costs.

Syntactically complex sentences have been shown to systematically activate Broca's area (left BA 44/45). Surprisingly, a number of studies investigating manipulations of working memory during sentence comprehension have observed not only activation in the inferior frontal gyrus (BA 44/45), but also activation in areas not normally associated with language (e.g., Stowe, Paans, Wijers, & Zwarts, 2004; see Christensen, 2008, 2010; Stowe, Haverkort, & Zwarts, 2005, for overviews). Among those non-linguistic regions are the motor and premotor cortex (the precentral gyrus, BA 4, 6), and regions associated with executive control such as the dorsolateral cortex (BA 9, 46) (see Kaan, 2002). It is important to mention that none of the tasks that observed

activation in classical motor areas involved any motor activity, only manipulation of representations in working memory (e.g. Hanakawa et al., 2002).

It has been reported that both theta and gamma band activity increases during maintenance of working memory representations (Gevins et al., 1997; Sarnthein et al., 1998; Raghavachari et al., 2001; Tallon-Baudry et al., 2001; Jensen and Tesche, 2002; Howard et al., 2003; Kaiser and Lutzenberger, 2005; Weiss et al. 2002). In addition to this, it has been proposed that there is functional interaction between these two rhythms during working memory maintenance (Lisman and Idiart (1995); for review, see Jensen, 2007).

Recently, there have been reports that activity in the alpha band is also modulated by working memory tasks. For instance studies investigating working memory operations by employing a Sternberg task observed that alpha activity increases with memory load during the retention interval (Jensen et al., 2002; Tuladhar et al., 2007). Based on this, some have suggested that increases in alpha activity reflect functional inhibition of the dorsal visual stream. The aim of the present study was to further elucidate the role of oscillatory activity during working memory maintenance.

## 5.2 Design & Method

### Participants

Twelve British participants (eight female and four male, mean age 21.2, range 19-25 years) with English as their native language participated in the MEG experiment, with approval of the local ethics committee (ethics approval reference number: FIMS00745). They were recruited from the participant pool of the Psychology Department of Glasgow University. Each participant was paid 6 pounds per hour for their participation and gave their informed consent prior to the experiment. All participants were right-handed with normal or corrected-to-normal vision.

**Materials**

The MEG data we present below provides new information about a specific type of syntactic ambiguity, namely the well-studied main verb/reduced relative clause ambiguity (see also Experiment 1). More specifically, we investigated the effect of cognitive workload on the processing of these syntactic "garden-path" sentences by embedding the main verb / reduced-relative ambiguity into structural complex sentences, and comparing each critical condition to their corresponding unambiguous control. These structural complex sentences either imposed a low load on working memory resources by employing a sentence-initial adverbial phrase (C1, C2) or a high load on working memory resources by introducing an additional referent in the initial phrase (C3, C4; cf. Gibson, 1998). For the critical item-set we designed 400 experimental items in four conditions each (see example below), of which 280 experimental items were selected for the final experiment. Each item consists of a full relative clause in a low load condition (C1, the correct control), the derived reduced-relative clause (C2), the syntactic 'complex' full relative clause (C3, correct control), and the corresponding syntactic complex *reduced* relative clause (C4), which was derived from (C3). The number of words up until the beginning of the embedded main clause was kept exactly the same across conditions. The experimental items were counterbalanced between 4 presentation lists such that each participant only saw one of the four conditions of an experimental item. In addition to this, 280 fillers, which were completely unrelated to the experimental items, were pseudo-randomly interspersed to distract from the experimental task.

| Low-load baseline (C1) | In the early afternoon the barman who was served by the waitress was tired. |
|---|---|
| Low-load garden-path (C2) | In the early afternoon the barman served by the waitress was tired. |
| High-load baseline (C3) | The beautician thought that the barman who was served by the waitress was tired. |
| High-load garden-path (C4) | The beautician thought that the barman served by the waitress was tired. |

## 5.3 Recordings

### 5.3.1 Apparatus

MEG data were acquired using a 248-channel (or SQUIDs; supraconducting quantum interference devices) whole head magnetometer (4D-Neuroimaging Magnes 3600 WH system, San Diego, CA, USA) at the CCNi at Glasgow University (for the exact sensor layout please refer to Appendix C.1). Online noise cancellation was performed using in-built software. A sampling rate of 508.63 Hz was used and the data were online band-pass filtered between 0.1 and 400 Hz. To synchronize the MEG data acquisition with the experimental event, trigger pulses were send through a parallel port connection at the start of each experimental sentence, the critical word onset (the preposition "by"), and for the response accuracy.

### 5.3.2 Procedure

First, the participant was prepared for the MEG, which took about 45 minutes on average to complete. Before the MEG preparation, participants received an elaborate written instruction with examples. Participants could go through the instructions in their own pace and were given the opportunity to ask questions afterwards.

During the preparation, head position indicator (HPI) coils were attached to the participant's head behind the right and left ears, above the nasion, and on the right- and the left-hand side of the forehead. The coil positions and head shape were digitized before the scan using the Polhemus program and stylus (Polhemus Isotrak, Kaiser Aerospace Inc, Colchester, Vermount, USA). Digitization allows to determine the head position in the MEG at the start and end of each block (maximum movement tolerated was 0.5 cm), and enables co-registration with the structural MRI for later source localization. Those participants that did not have a structural MRI were subsequently scanned by the Research Radiographer Frances Crabbe using the CCNi 3T Siemens Trio MRI (Siemens Medical Solutions, Erlangen, Germany).

The experiment has been implemented with E-Prime 2.0 and it comprised seven experimental blocks in total. Each experiment started with a short practice block to familiarize the participant with the task. The seven experimental blocks were divided into larger parts of three blocks. The large blocks (which consisted in fact of two experimental blocks) were paused in between, enabling the participant to take a short break in which they were able to rest their eyes. Each of these 3 larger parts lasted about 30 minutes. Between these large blocks there was a large break where the head position were acquired to determine how much the participant moved between start and end of the experimental block. The last block only took about 15 minutes to complete.

At the end of the MEG experiment, participants were taken out of the MEG shielded room and were fully debriefed about the purpose of the experiment and paid for their participation.

### 5.3.3 Design

The experiment consisted of a two-by-two design with the factors cognitive load (low, high) and ambiguity (baseline, garden-path). The experimental procedure was as follows: The participant pressed a key to start the experiment. This was followed by a 500ms blank screen and then by a fixation cross in the center of the screen. Each sentence was presented word-by-word and followed by a short Yes/No-comprehension question, which the participant answered by pressing the left key or the right key of the Lumitouch response pad provided. Each word appeared in the center of the screen for a duration of 300ms each, and with an inter-stimulus interval of 200ms. Four different lists were created and each was given to 3 participants.



*Figure 31: Schematic illustration of the experimental procedure of the MEG experiment*
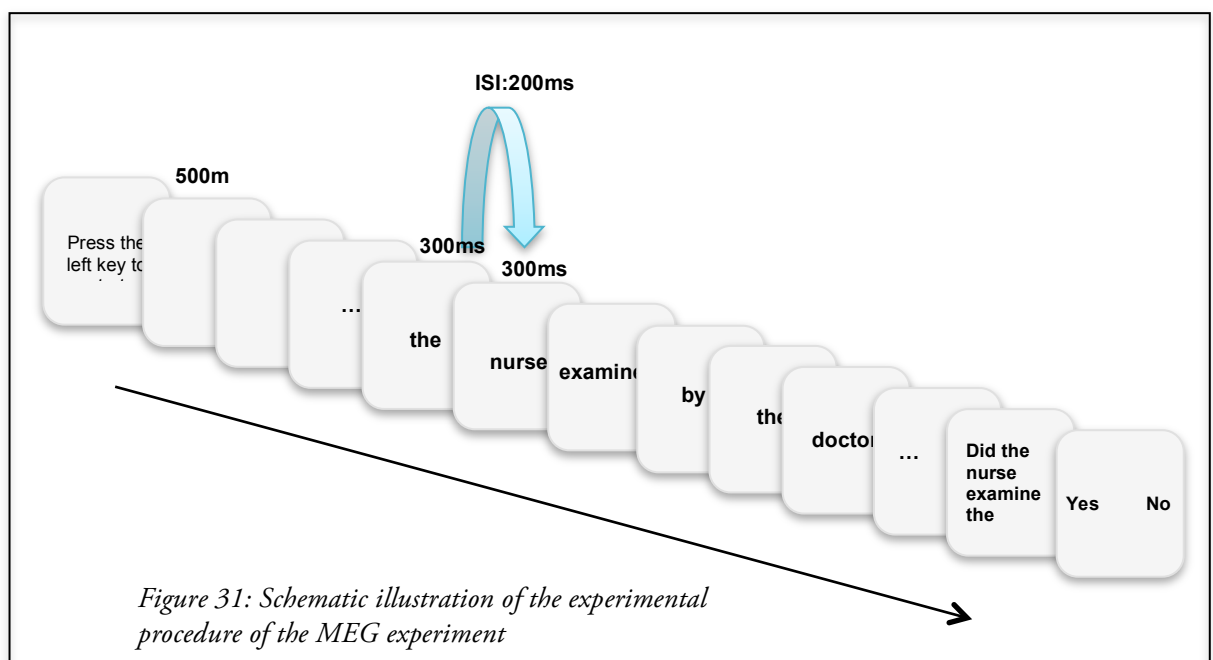
### 5.4 MEG Data-analysis

Participants' MEG signal was recorded in seven separate blocks per experimental session and subsequently pre-processed and analysed using the open source Matlab toolbox Fieldtrip (Oostenveld, Fries, Maris, and Schoeffelen, 2011; http://www.ru.nl/fcdonders/fieldtrip). Anatomical and functional data were analysed using SPM8 (http://www.fil.ion.ucl.ac.uk/spm/software/spm8/) in order to project sources of oscillatory activity onto the brain.

### 5.5 ERF Analysis

### 5.5.1 Pre-processing

The first pre-processing steps were performed on the recording block level. For the sensor-level analysis on the event-related fields the data was segmented starting 500ms before the onset of the disambiguating word (the preposition "by") until 2s after it. A dft-filter was applied to remove the line noise of 50Hz (and the harmonics of 100 and 150Hz), and the data was detrended to prepare for later Independent Component Analysis (ICA). To make the dft-filter very precise, the trials were zero-padded to 10 seconds.

Following these initial preprocessing steps, the separate recording blocks were concatenated and denoised by performing a principal component analysis (PCA). This method allows to reduce the noise in the magnetometer data by computing balancing coefficients, which are then used to subtract a weighted combination of the signals measured at the reference channels from the signals measured at the magnetometer coils. After denoising, the data were visually inspected for bad channels (not more than five channels per participant), which were then removed from the data. The data containing only the good channels was visually examined and cleaned from bad trials on the recording block level. MEG is highly sensitive not only to artifacts due to eye movements, SQUID jumps, and muscle tension, but it is also very susceptible to the

change of the blood flow in the brain in response to the actual heartbeat. To clean the data from eye blinks and heart artifacts, an ICA component analysis limited to 40 components was performed on the electromagnetic brain signals of the concatenated recording blocks (e.g. Escudero, Hornero, Abasolo, Fernandez, & Lopez-Coronado, 2007; Jung et al., 2001; Onton, Westerfield, Townsend, & Makeig, 2006). After a second visual inspection of the data for bad trials, bad channels in the MEG were repaired by replacing them with the average of their nearest neighbours using a surface Laplacian interpolation (see e.g. Perrin et al., 1989). Note that this was only done for bad channels that did not adjoin other bad channels, as this method is not valid to repair multiple bad channels that are next to each other. Subsequently, the data for each condition separately was filtered using a band-pass filter of 0.5-35Hz, baseline corrected using a baseline time window of 200ms before the critical word onset, and averaged over trials on the single-subject level. For the sensor-level analysis, an estimate of the planar gradient for each individual sensor was calculated by using the signals of their neighboring sensors (e.g. Bastiaansen and Knosche, 2000). More precisely, the planar gradient at a given location was computed in both the horizontal and vertical direction and subsequently combined using a function that is based on the rule of Pythagoras. The planar gradient transformation is advantageous as it simplifies the interpretation of the sensor-level data because the maximal signal power is typically located above the source (Hämäläinen et al., 1993).

### 5.5.2 Statistical Analysis: ERF

The significance of the difference between the garden-path condition and the corresponding control condition using the combined planar gradient data was established by using a nonparametric cluster randomisation test (Nichols and Holmes, 2002; E. Maris and R. Oostenveld, 2003). This nonparametric randomisation test effectively controls for multiple comparisons problem by clustering neighboring sensor pairs that exhibit the same effect. The same test was used to identify differences between the low load garden-path condition compared to the high load garden-path conditions in the baseline time window before the critical word onset (the first four words), and at the point of disambiguation (critical word onset). The time segments that entered the analysis were defined between 0s (onset of the critical word "by") until 1s after critical word onset, which is in agreement with the time course of memory related effects as indicated in ERP studies. This nonparametric statistical test uses a test statistic (the maximum of the cluster-level statistics) in which the calculation is based on a thresholded sample-specific t statistics. For a nonparametric test, it is irrelevant whether these sample-specific t statistics have a T distribution under the null hypothesis.

More precisely, the randomisation method identified sensors whose t statistics exceeded a critical value when comparing two conditions sensor by sensor ($p < 0.025$, two-sided). This first step identifies sensors with effects exceeding a threshold for the subsequent cluster analysis and has the advantage that it is not required that the power values that enter the analysis are normally distributed. To correct for multiple comparisons, neighboring sensors (defined by a distance of 3.7cm, on average 6.8 sensors) that were below the critical value were grouped as a cluster. The cluster-level test statistic was determined by the sum of the t values of the sensors in a given cluster and the cluster with the maximum sum was used as the test statistics. The type I error rate for the 248 sensors was controlled by evaluating the cluster-level test statistic under

the randomisation null distribution of the maximum cluster-level test statistic. To achieve this, the data between the contrasting conditions were randomized across all subjects calculating t statistics for the new set of clusters using 1000 randomisations. The p-value was estimated based on the proportion of the randomisation null distribution exceeding the observed maximum cluster-level test statistic (the MonteCarlo p-value).

### 5.5.3 Source localization of the ERF effects

To localize the evoked field, we applied a Linearly-Constrained Minimum Variance (LCMV) beamformer. Similar to the DICS beamforming technique, this method constructs a 3D spatial distribution of the power of the neuronal sources. Following this, the distribution is then overlaid on the subject's structural MRI image. Importantly, the resulting distributions of source power can then be subjected to statistical analysis.

In order to employ the LCMV beamforming method, a second timelock-analysis was performed to obtain the covariance-matrix in the interesting latency window of the averaged single trials between all sensor pairs of the 248-sensor 4D-neuroimaging magnetometer system. Before applying the actual beamformer technique, it is necessary to construct a forward model (or headmodel) for each individual subject. More precisely, the forward model makes it possible to calculate an estimate of the field distribution that is measured by the MEG sensors. As this was done analogous to the DICS beamformer technique on the oscillatory activity, please refer to section 5.7.2., which gives a detailed description of this initial step. When using a beamformer technique to reconstruct sources for two or more conditions, there are two different options how to compute the spatial filters: One approach is to generate spatial filters separately for each condition, while the second approach uses the combined conditions to compute a common filter. Typically, it is beneficial to use common spatial filters as the combined datasets of the

conditions result in larger data. The rule of thumb is that the more data are available, the better the estimate which in turn leads to more sound filters. The LCMV source-analysis output was again subject to a nonparametric cluster randomisation test using a maximum cluster-level test statistic with 1000 randomisations.

### 5.5.4 ERF Analysis Results

#### 5.5.4.1 Low-load Garden-Path condition vs. Baseline condition

The cluster randomisation method identified three negative sensor*time-clusters for the garden-path condition compared to the control condition. The first significant effect was represented by an early negative cluster between 0-210ms over left anterior-frontal and anterior-temporal sensor areas (p=0.004 (*), see Figure 32). A second long-lasting cluster reached significance in a latency of 235ms to 700ms after critical word onset (p=0.0009(*)), while the third cluster emerged in the later time window of 778-998ms post-stimulus. These late effects were confined to left-anterior surface areas.
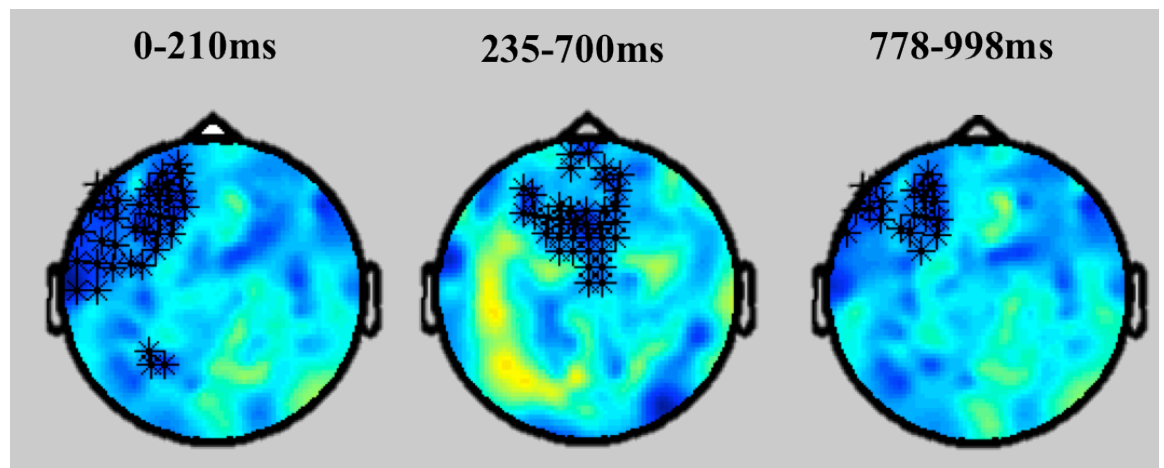


*Figure 32: Statistical map of the negative cluster ERF effect of the low-load garden-path conditions compared to the unambiguous control conditions plotted on the planar gradient data and averaged for the significant latencies (0-210ms, 235-700ms, 778-998ms). Significant channel*time pairs are highlighted by '*'.*

### 5.5.4.2 High-load Garden-Path condition vs. Baseline condition

The cluster randomisation analysis on the event-related fields for the high-load garden-path condition compared to the unambiguous control identified comparable effects as the ones observed in the low-load condition contrast. However, these effects were far more pronounced in the high-load condition contrast: The non-parametric randomisation identified three negative sensor*time clusters (negative cluster 1: time window = 0-230ms, p= 0.0009(*); negative cluster 2: time window = 232-499ms, p = 0.002(*); negative cluster 3: time window = 800-1000ms, p = 0.004 (*); see Figure 33) We observed a left-anterior cluster already shortly after critical word onset (0-50ms), which spread in the latency of 50-100ms to temporo-parietal areas of the left hemisphere (see Figure 32). The anterior cluster extended to bilateral anterior areas in the latency of 150-200ms, while returning to left-anterior sensor areas between 230-499ms post-stimulus. The late negative cluster between 800-1000ms was mostly confined to anterior areas over both hemispheres.
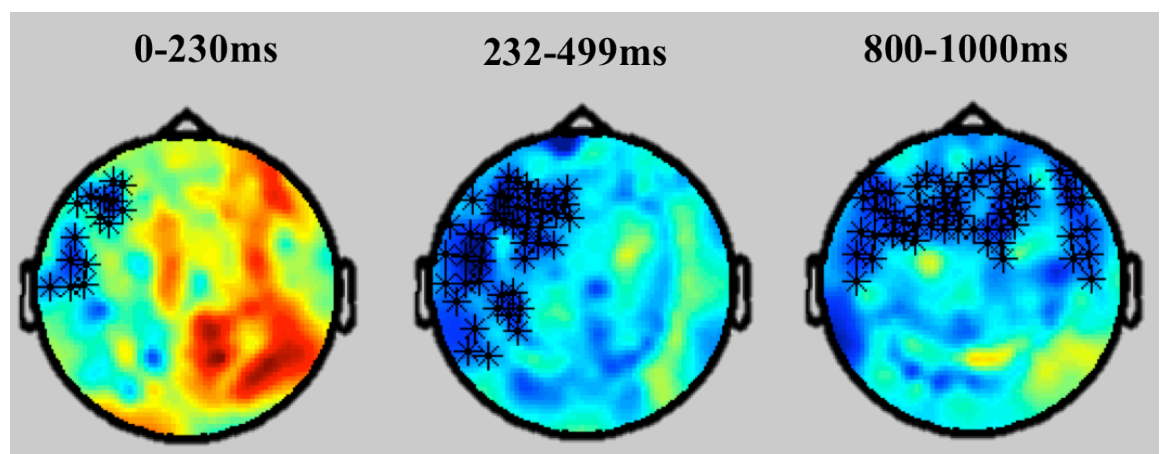


*Figure 33: Statistical map of the negative cluster ERF effect of the high-load garden-path conditions compared to the unambiguous control conditions plotted on the planar gradient data and averaged for the significant latencies (0-230ms, 232-499ms, 800-1000ms). Significant channel*time pairs are highlighted by '*'*

### 5.5.4.3 Simple effect 'load': High-load garden-path vs. low-load Garden-path

The only effect that survived the direct contrast between the two garden-path conditions was a negative cluster in a latency range of 60ms to 145ms post-stimulus (p=0.002(*)). This effect started out over left temporal sensor areas before moving to left anterior sensor areas. Figure 34 depicts the statistical map of the load effect on the sensor-level for the high-load garden-path condition compared to the low-load garden-path condition at the critical word "by". Significant sensor*time pairs are highlighted by '*'.
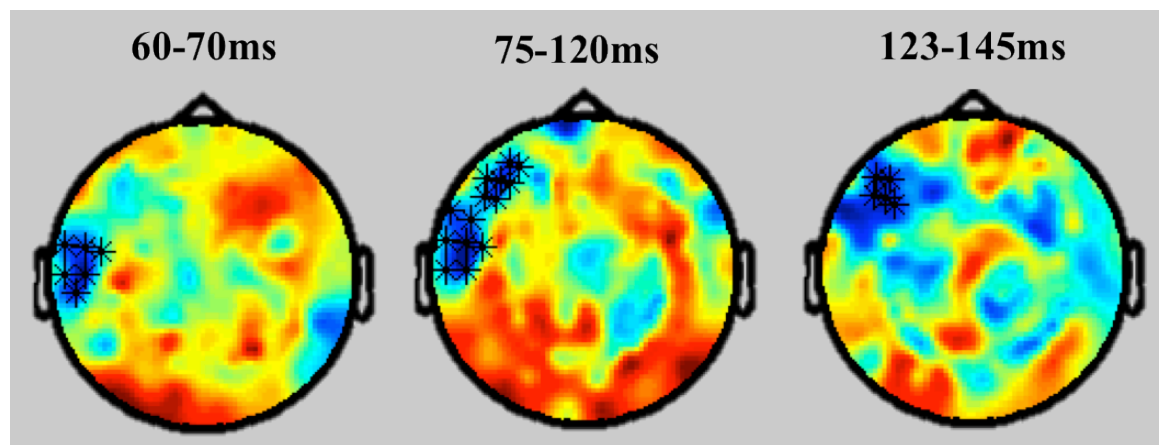


*Figure 44.A: Topographic plot of the sensor level ERF results for the high-load garden-path conditions compared to low-load garden-path conditions (the simple effect 'load') between 60 and 145ms after critical word onset ("by"), represented by a significant negative cluster (p=0.002(*)). Significant channel*time-pairs are highlighted by '*';*
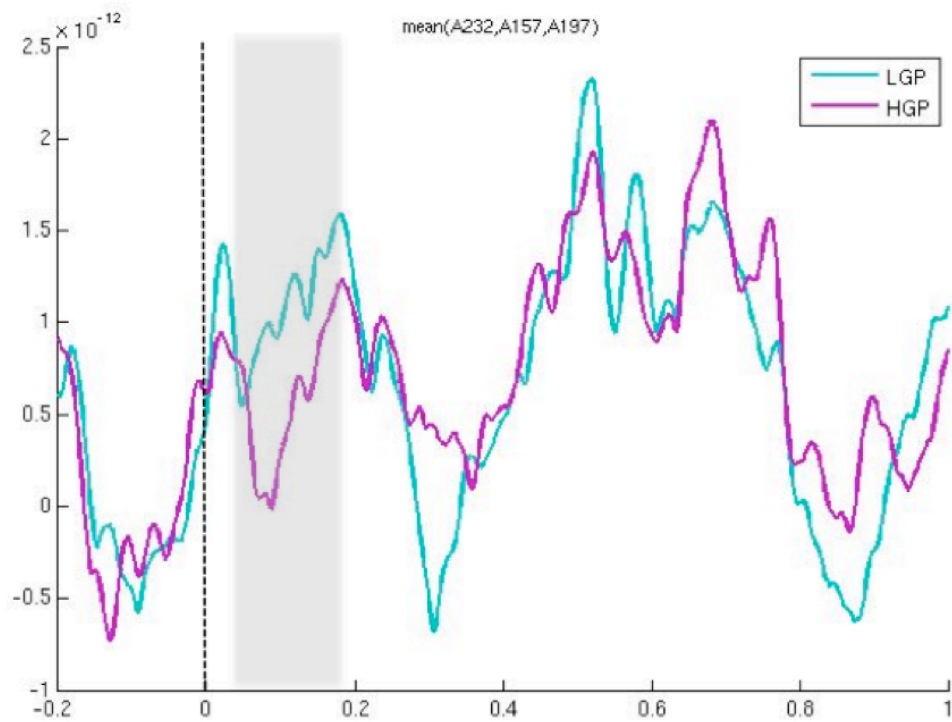
*Figure 34.B: Mean grandaverage of three representative left temporal sensors (A232, A157, A197) of the high-load garden-path condition (HGP, pink) and the low-load garden-path condition (LGP, blue) at three representative left fronto-temporal sensors*

### 5.5.4.4 Baseline effects high-load garden-path vs. low-load garden-path

The cluster randomisation analysis did not identify any significant differences for the baseline time-windows (before the critical word onset "by") between the high-load vs. low-load garden-path conditions ($p > 0.25$ (n.s.)).

### 5.5.5 Source Localization Results (LCMV beamforming technique)

The following section will first describe the localization of the above reported early ERF effects (0-200ms) for the simple effects between the garden-path conditions (high-load/ low-load) to their respective control condition (baseline condition). Then we will report the results of the simple effect 'load' by localizing the effect of the high-load garden-path conditions compared to the low-load garden-path conditions. As we cannot

test for interactions using a non-parametric randomisation procedure, we tried to isolate the main effect 'ambiguity' by concatenation all garden-path conditions (high-load and low-load) and comparing this to the concatenated control conditions (high-load baseline and low-load baseline). Similarly, we tested the main effect 'load' by subtracting the respective control condition from their corresponding garden-path condition (high-load / low-load) and comparing the resulting differences to each other. It is important to mention that for source reconstruction, we used the data from the true axial sensors and not the planar gradient estimate. The significance of the difference between the above described condition contrasts in source space was again established using a non-parametric randomisation test (e.g. Oostenfeld et al., 2011). Please refer to Table 3 for a summary of the results of the functional localization for the ERF effects.

### 5.5.5.1 Low-load Garden-Path condition vs. Baseline condition

The significance of the difference between the low-load garden-path condition compared to the non-ambiguous control revealed two sources (p=0.002(*), time=0.06 to 0.145s): The local maximum for the negative cluster activated bilaterally the superior temporal gyri (left: Brodmann area 22, range = 0; right Brodmann area 22; range=1), while another source localized in the left middle frontal gyrus (Brodmann area 6, range=1). Brodmann area 22 is a region typically activated during the syntactic processing of sentences and is considered inherently linguistic, whereas Brodmann area 6 has been shown to be sensitive to syntactic errors (for review see Kaan & Swaab, 2002). Figure 35.A. depicts the functional source reconstruction of the statistical significant sources projected on an inflated surface brain, Figure 35.B. depicts the effects as 2D-slice visualisation.
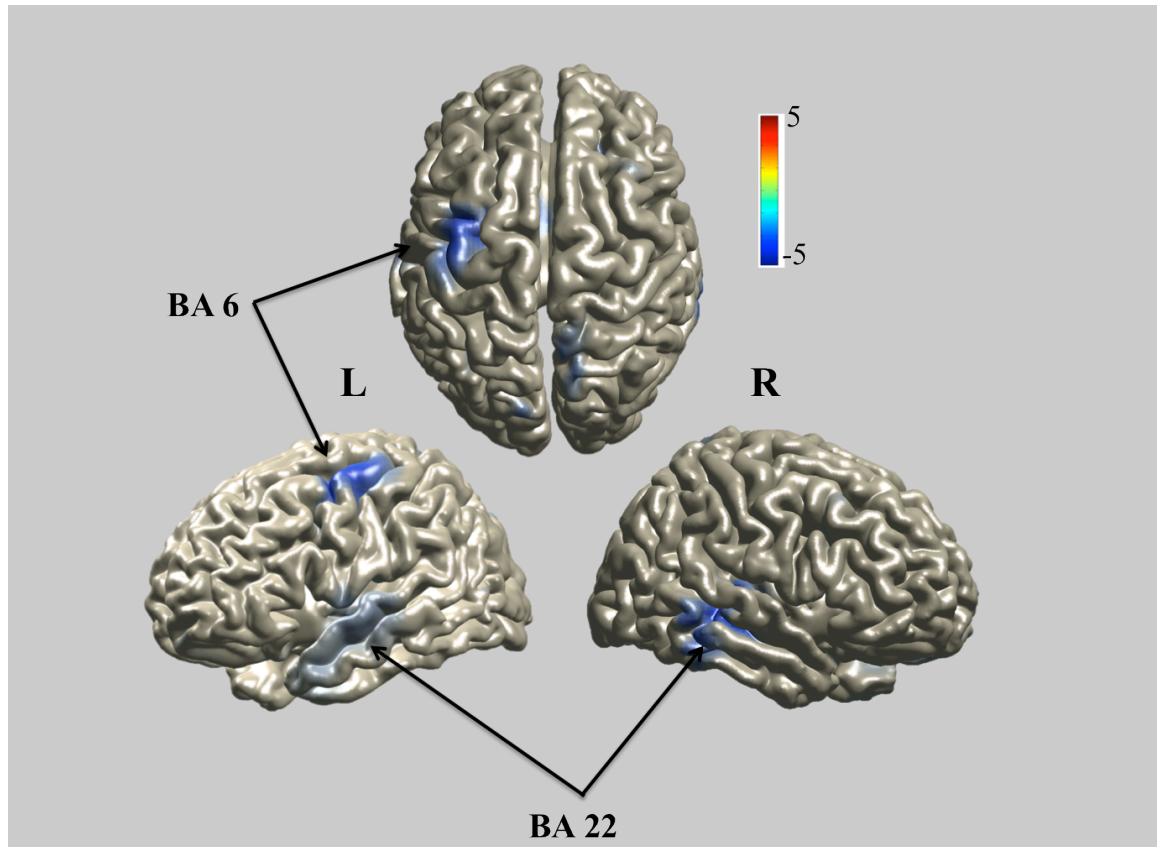
*Figure 55.A: Functional source reconstruction of the statistical significant sources of simple effect low-load garden-path conditions vs. baseline conditions projected on an inflated brain. Significant sources localised bilaterally in superior temporal gyri (BA 22) and left middle frontal gyrus (BA 6).*
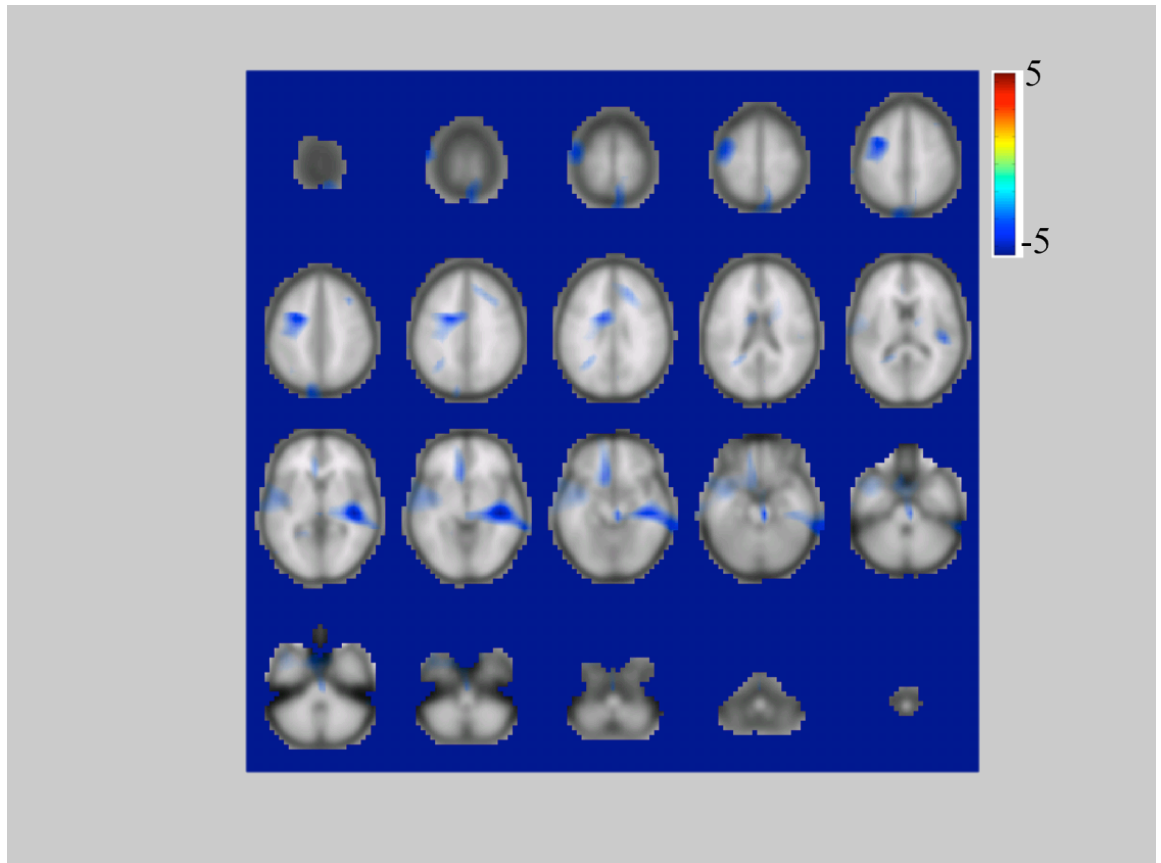
*Figure 35.B: 2D-slice visualisation for functional source reconstruction of the statistical significant sources of simple effect low-load garden-path conditions vs. baseline conditions. Significant sources localised bilaterally in superior temporal gyri (BA 22) and left middle frontal gyrus (BA 6).*

### 5.5.5.2 High-load Garden-Path condition vs. Baseline condition

The non-parametric randomisation test revealed one significant source for the simple effect high-load garden-path condition compared to the non-ambiguous control conditions ($p=0.009(*)$, time=0.06 to 0.23s): The local maximum for the negative cluster localized in the left frontal lobe or more precisely the left dorsolateral prefrontal cortex (dlPFC, Brodmann area 9; range=3) and the right superior temporal gyrus (BA 39). Figure 36.A. above shows the functional source reconstruction of the statistical significant sources projected on a surface brain while Figure 36.B represents a 2D-slice visualization of these effects.
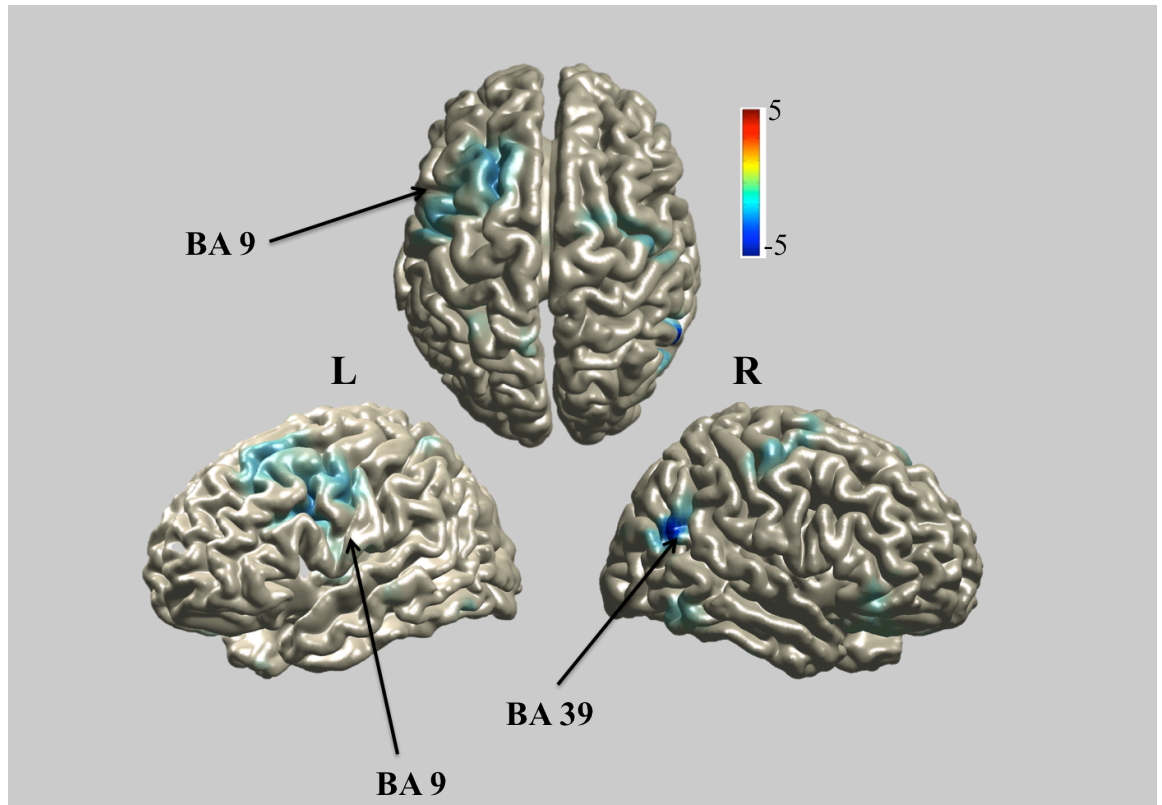
*Figure 36.A.: Functional source reconstruction of the statistical significant sources of simple effect high-load garden-path conditions vs. baseline conditions projected on an inflated brain. Significant sources localised bilaterally in left frontal lobe (BA 9) and right superior temporal gyrus (BA 39).*
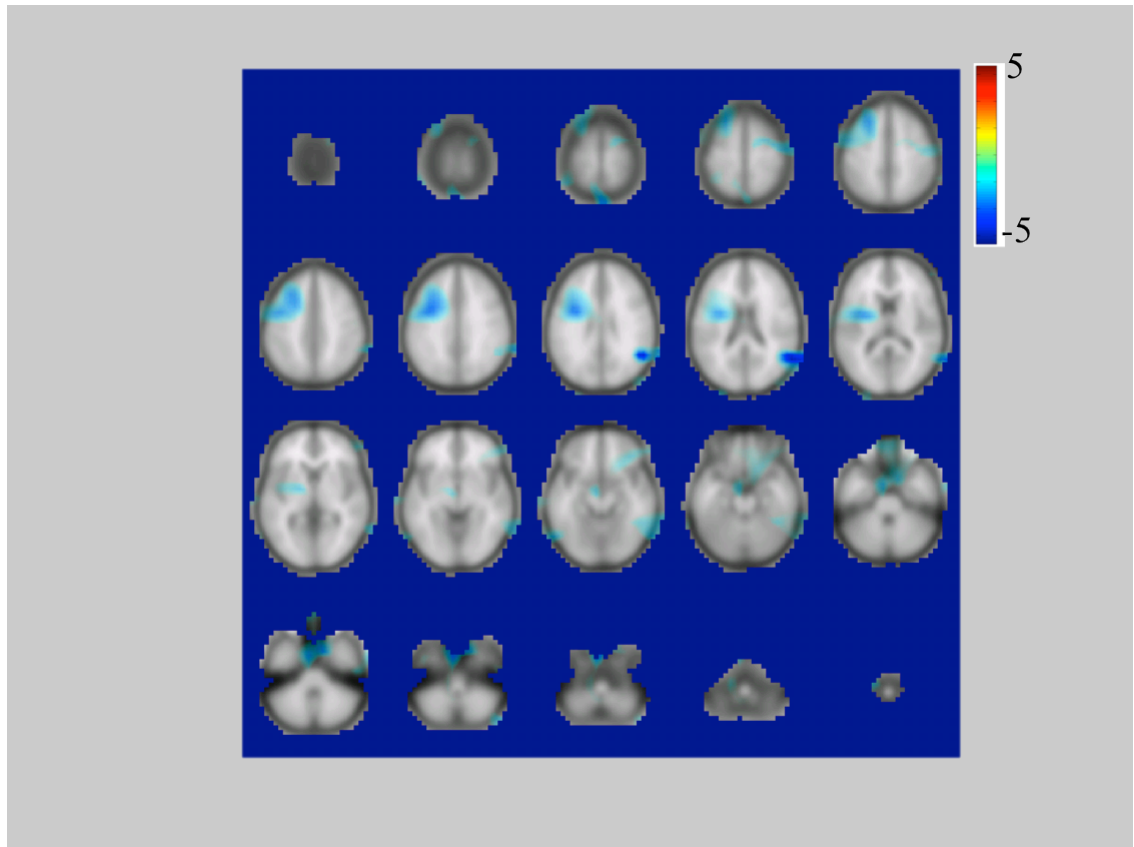
*Figure 36.B: 2D-slice visualisation of the statistical significant sources of simple effect high-load garden-path conditions vs. baseline conditions in left frontal lobe (BA 9) and right superior temporal gyrus (BA 39).*

### 5.5.5.3 High-load Garden-Path condition vs. Low-load Garden-Path condition

To localize the simple effect 'load' due to the degree of structural complexity (high-load vs. low-load) we compared the high-load garden-path condition to the low-load garden-path condition. The nonparametric randomisation effect revealed significant sources solely in left hemisphere regions: The sources accounting for the simple effect 'load' localised in left inferior frontal gyrus (Brodmann area 45) and left superior frontal gyrus (Brodmann area 10) ($p = 0.02$ (*), time = 0.06 to 0.23s; range = 0; see Figure 37.A and 37.B below). Commonly, the left inferior frontal gyrus and Broca's area in particular is linked to linguistic processing. Importantly, there have been a number of syntax-related studies (Friederici & Frisch 2000; Friederici et al. 2006a, 2006b; Grodzinsky & Friederici 2006; Bahlmann et al. 2008; Friederici 2009) suggesting that this region is

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involved in the processing *complex clauses* or longer-distance dependencies. In addition to this, Broca's area has also been implied in the detection of conflicts and the recruitment of control mechanisms for resolving incompatible information (e.g. January et al, 2008). Interestingly, the superior frontal gyrus and specifically bilaterally BA 10 has been implied to participate during working memory (WM) maintenance.
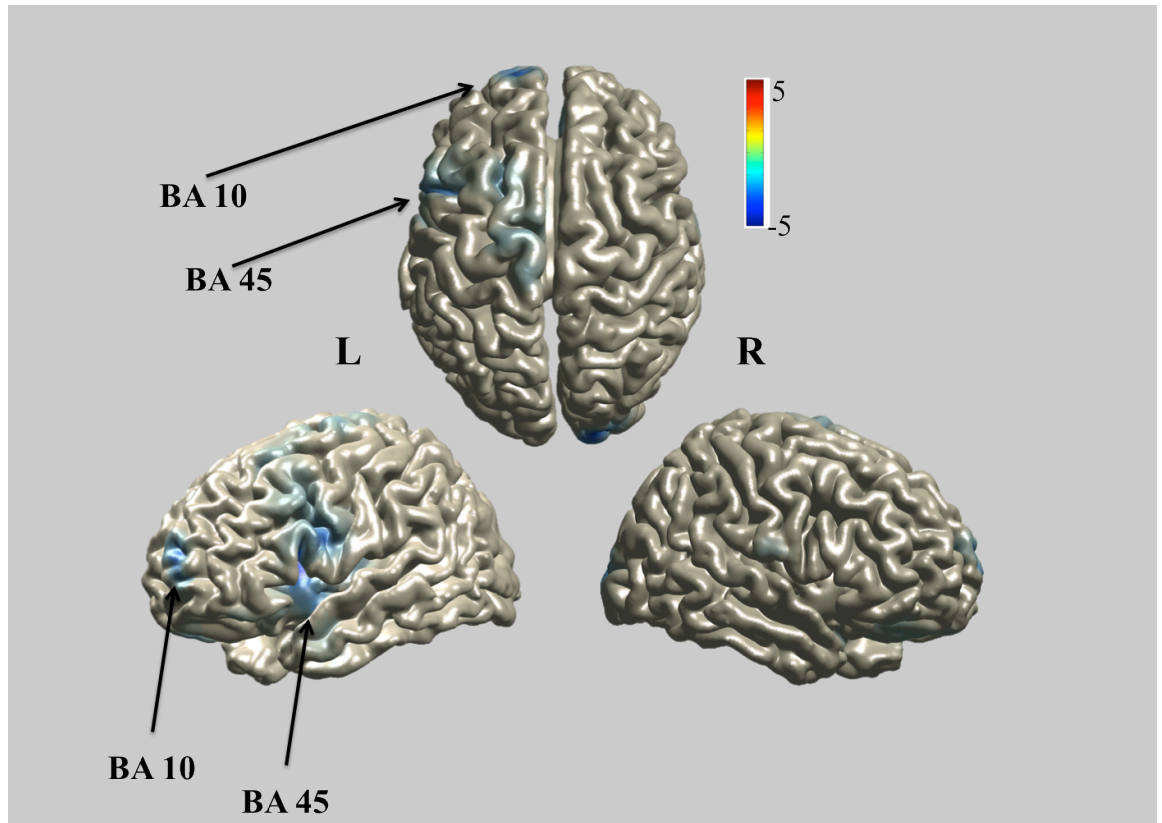


*Figure 37.A: Functional source reconstruction of the statistical significant sources of simple effect 'load' for the difference between high-load garden-path conditions vs. low-load garden-path conditions projected on an inflated brain. Significant sources localised in left hemisphere regions with activation in left inferior frontal gyrus (BA 45) and left superior frontal gyrus (BA 10).*
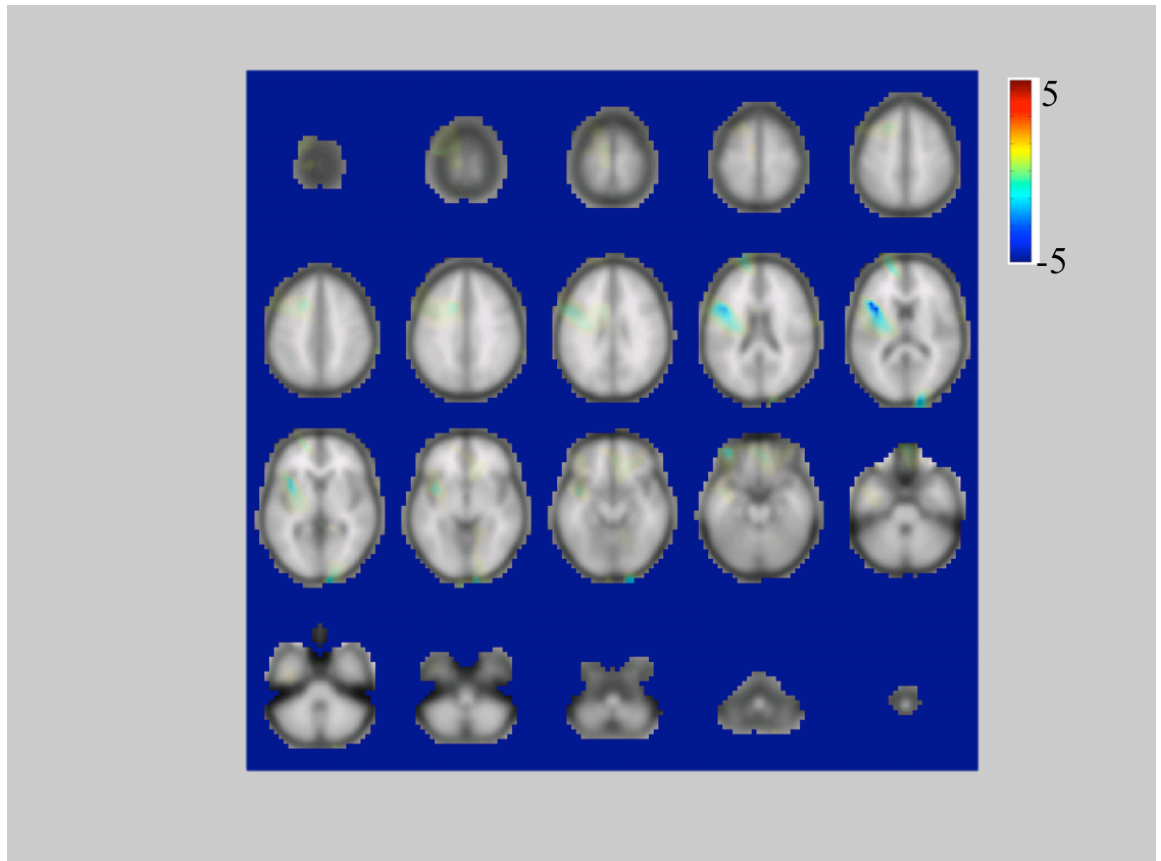
*Figure 37.B: 2D-slice visualisation of the statistical significant sources of simple effect 'load' for the difference between high-load garden-path conditions vs. low-load garden-path conditions projected on an inflated brain. Significant sources localised in left hemisphere regions with activation in left inferior frontal gyrus (BA 45) and left superior frontal gyrus (BA 10).*

### 5.5.5.4 Main effect 'ambiguity': Garden-path conditions vs. Baseline conditions

To establish the main effect 'ambiguity' we concatenated all garden-path conditions (high-load and low-load) and compared those to the concatenated correct control conditions (high-load baseline and low-load baseline). The cluster-randomisation test revealed two sources ($p = 0.009$ (*)). As depicted in Figure 38.A. and Figure 38.B, the DICS source localisation determined sources in the right inferior frontal gyrus (Brodmann area 47, range = 3), the right superior parietal lobe (BA 7), the right middle temporal gyrus (BA 19), and the left middle frontal gyrus (BA 6).
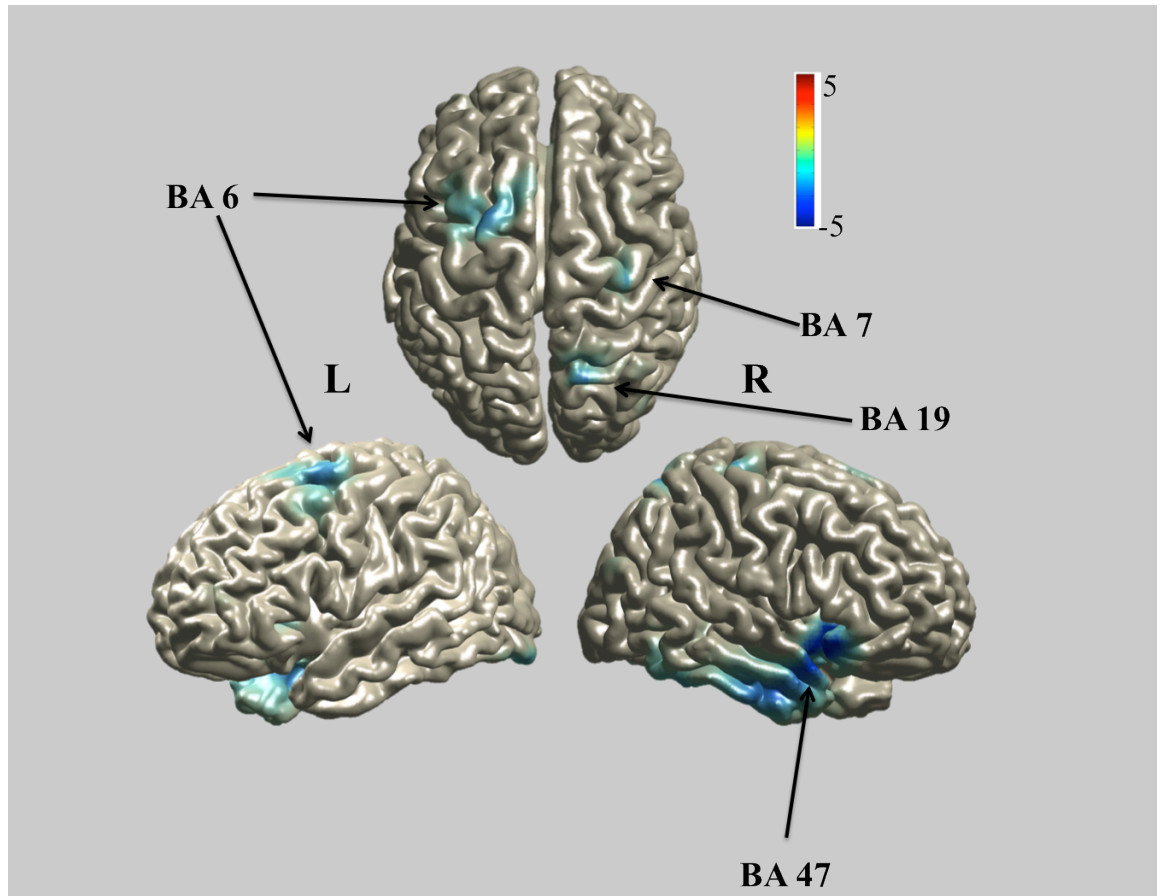
*Figure 38.A: Surface projection of the significant sources for the main effect 'ambiguity' of all garden-path condition compared to baseline conditions with source activation in the right inferior frontal gyrus (BA 47), the left middle frontal gyrus (BA 6), the right superior parietal lobe (BA 7), and the right middle temporal gyrus (BA 19)*
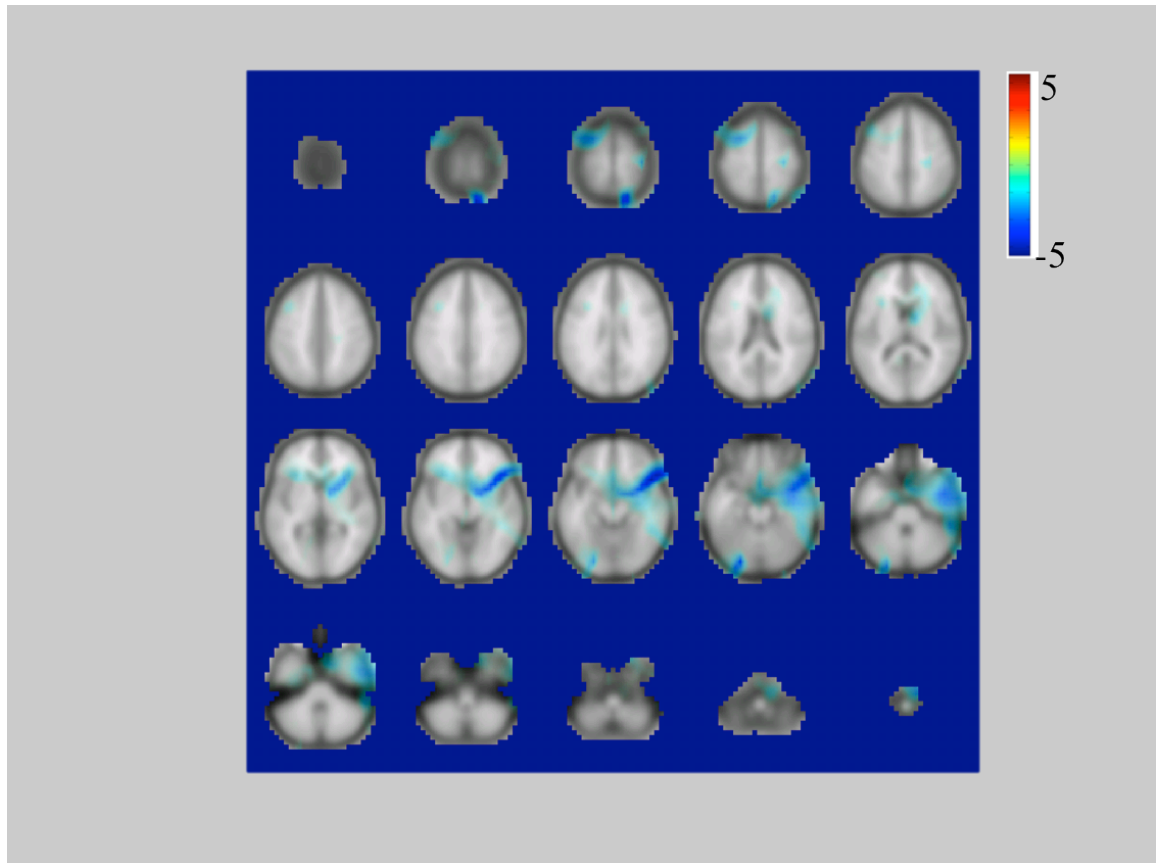
*Figure 38.B: 2D-slice visualisation of the significant sources for the main effect 'ambiguity' of all garden-path condition compared to baseline conditions with source activation in the right inferior frontal gyrus (BA 47), the left middle frontal gyrus (BA 6), the right superior parietal lobe (BA 7), and the right middle temporal gyrus (BA 19)*

Typically, activation in left BA 47 has been associated with working memory and executive aspects of semantic processing (e.g. Poldrack et al. (1999)). Similarly, the middle frontal gyri and among those the left lateral BA 6 has been related to correlate with working memory, serially updating verbal information, and error detection (e.g. Rypma et al. (1999); Tanaka et al. (2005), Menon et al. (2001)).

### 5.5.5.5 Main effect 'load': High-load Garden-path vs. Low-load Garden-path

To localize the main effect 'load' due to the degree of structural complexity we used the differences of the garden-path conditions minus their respective baseline condition and entered the resulting differences into the cluster randomisation test. The nonparametric randomisation effect uncovered left-lateral sources analogous to the one observed for the simple effect 'load': the maximum activity localized in Broca's area (Brodmann area 45, $p = 0.02$ (*), time = 0 to 0.230; range = 0; see Figure 39.A. and 39.B.). In addition to this, there was weaker activation in the left superior frontal gyrus (BA 10). It is intriguing, that this effect appears to mirror the observed effects for the simple effect 'load'. This may suggest, that BA 45 and BA 10 are indeed related to WM maintenance during the processing of syntactically complex sentences.
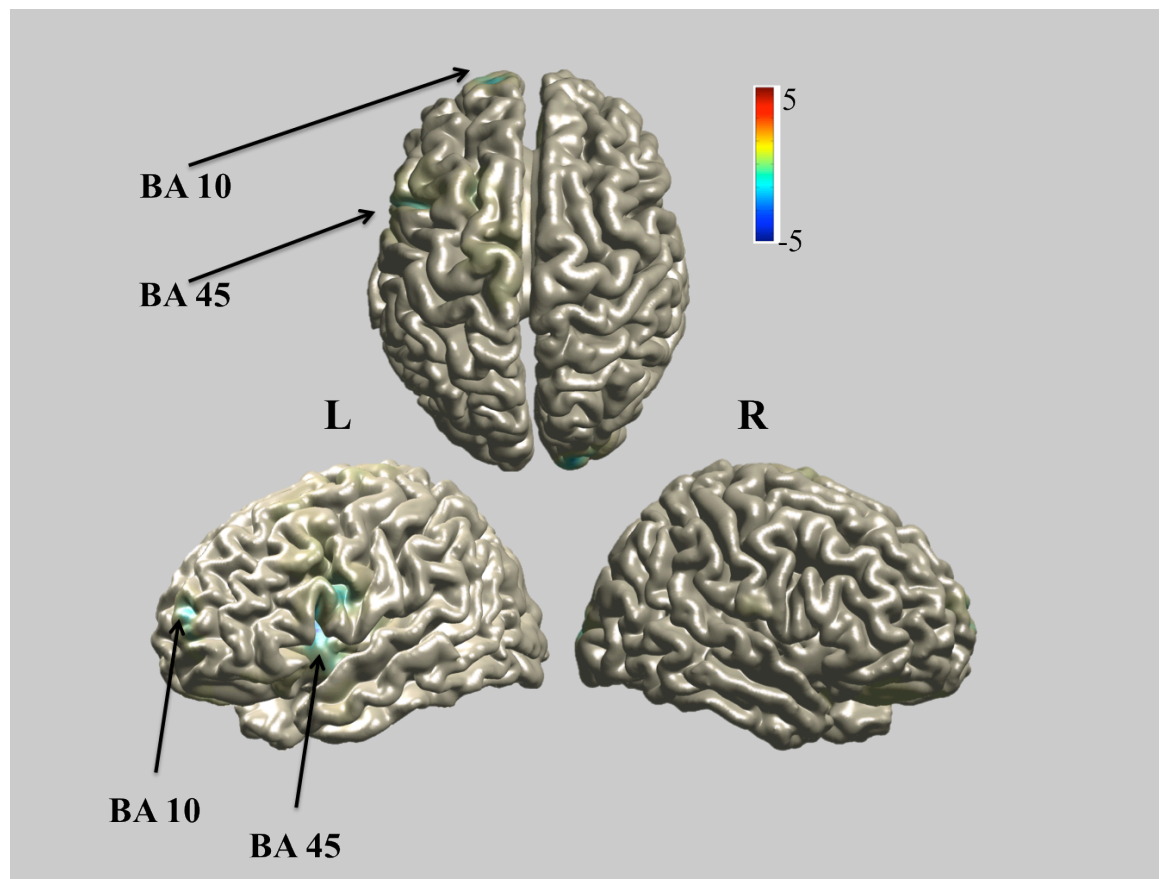


*Figure 39.A: Surface projection of the significant sources for the main effect 'load' for the comparison of the differences between high-load garden-path condition minus baseline conditions and low-load garden-path conditions minus baseline. Significant source activation was found in left inferior frontal gyrus (BA 45), the left superior frontal gyrus (BA 10).*
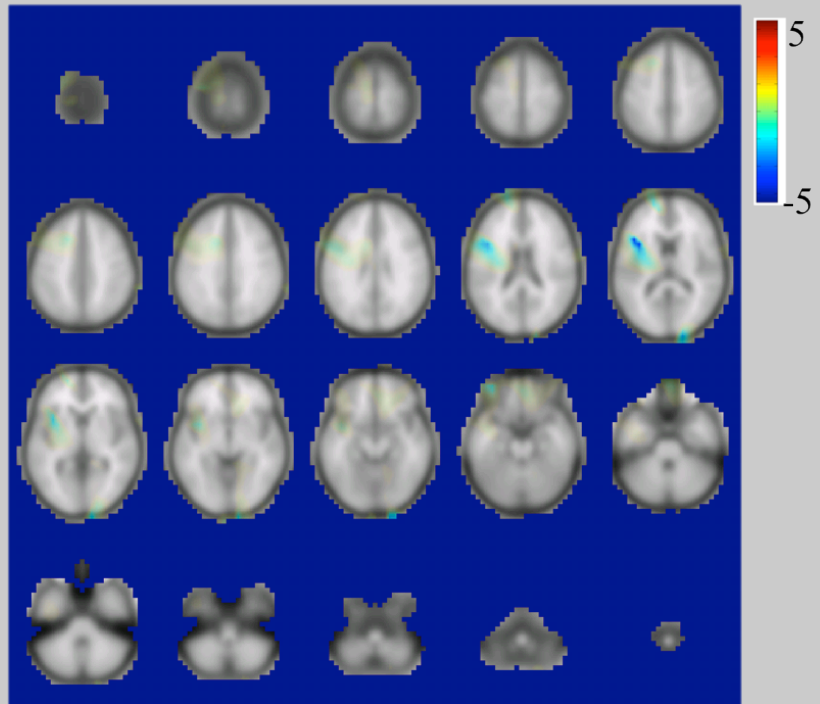
*Figure 39.B: 2D-slice visualisation of the significant sources for the main effect 'load' (the comparison of the differences between high-load garden-path condition minus baseline conditions and low-load garden-path conditions minus baseline). Significant source activation was found in left inferior frontal gyrus (BA 45), the left superior frontal gyrus (BA 10).*

| Contrast | Activation peak | BA | Significance (*) | x | y | z | Range |
|---|---|---|---|---|---|---|---|
| Low-load GP vs. Baseline | Right Cerebrum, Temporal Lobe, Superior Temporal Gyrus | 22 | p = 0.002 (*) | 44 | -42 | 4 | 1 |
| | Left Cerebrum, Temporal Lobe, Superior Temporal Gyrus | 22 | | -54 | -4 | -6 | 0 |
| | Left Cerebrum, Frontal Lobe, Middle Frontal Gyrus | 6 | | -34 | -4 | 46 | 1 |
| High-load GP vs. Baseline | Left Cerebrum, Frontal Lobe, Precentral Gyrus | 9 | p = 0.009 (*) | -32 | 6 | 34 | 3 |
| | Right Cerebrum, Temporal Lobe, Superior Temporal Gyrus, Gray Matter, Brodmann area 39, Range=1 | | | | | | |
| High-load GP vs. Low-load GP | Left Cerebrum, Frontal Lobe, Inferior Frontal Gyrus | 45 | p = 0.02 (*) | -42 | 18 | 10 | 0 |
| | Left Cerebrum, Frontal Lobe, Superior Frontal Gyrus | 10 | | -20 | 68 | 14 | 1 |
| Main effect 'ambiguity' (high-load and low-load) vs. Baseline (high-load and low-load) | Right Cerebrum, Frontal Lobe, Inferior Frontal Gyrus | 47 | p = 0.009 (*) | 48 | 24 | -8 | 3 |
| | Left Cerebrum, Frontal Lobe, Middle Frontal Gyrus | 6 | | -34 | -4 | 64 | 2 |
| | Right Cerebrum, Parietal Lobe, Superior Parietal Lobule | 7 | | 16 | -62 | 60 | 1 |
| | Right Cerebrum, Temporal Lobe, Middle Temporal Gyrus | 19 | | 52 | -82 | 20 | 2 |
| Main effect 'Load' | Left Cerebrum, Frontal Lobe, Inferior Frontal Gyrus | 45 | p= 0.02(*) | -42 | 18 | 10 | 0 |
| | Left Cerebrum, Frontal Lobe, Superior Frontal Gyrus | 10 | | -22 | 68 | 16 | 2 |

*Table 3: Summary of the functional source localization for the ERF effects.*

## 5.6 TFR Analysis

### 5.6.1 Preprocessing

The preprocessing pipeline for the time-frequency representations was similar as the one performed on the event-related fields: The first pre-processing steps were performed on the recording block level, and the data was segmented starting 1s before the onset of the disambiguating word (the preposition "by") until 2s after it. We applied a dft-filter, detrended the data, and zero-padded the trials to 10 seconds. In contrast to the ERF analysis, no baseline correction was performed at this point.

Similar to the ERF analysis the separate recording blocks were then concatenated and denoised by performing a principal component analysis (PCA). Subsequently bad channels were removed from the data and the data was visually examined and cleaned from bad trials on the recording block level. The data was then cleaned from eye blinks and heart artifacts by applying an ICA component analysis for each of the 248 sensors on the concatenated recording blocks (as opposed to reducing the ICA components which was done for the ERF analysis). As we plan to carry out functional connectivity analysis at a later stage, it is recommended not to reduce the number of ICA components as this also leads to a reduction of the phase space. Subsequently, the data was again visually inspected for bad trials and bad channels were repaired by using a surface Laplacian interpolation.

### 5.6.2 Statistical Analysis: TFR and Source localization

We chose our frequency ranges of interest to be 4-7Hz (theta frequency), 8-14Hz (alpha frequency), 14-30Hz (beta frequency), and 30-130Hz (gamma frequency). These frequency ranges are compatible with previous reports on oscillatory activity associated with working memory demands. We used an analysis time window starting with the critical word onset (0s) and ending 1s after it. For the theta, alpha, and beta frequency band we calculated time frequency representations using a Hanning taper with 4 cycles for a 1 second time-window. The frequency resolution is defined according to the length of the time window (1/length of time window in seconds), thus resulting in a 1 Hz frequency resolution (1/1 sec= 1Hz). As oscillatory gamma band activity is comparatively broad in width and benefits from multitapering, time frequency representations were estimated using a multitaper spectral estimation method (e.g. Percival & Walden (1993)). Generally, more tapers for a given time window will result in greater smoothing, which is particularly beneficial for electrophysiological brain signals above 30 Hz. Therefore, a frequency-dependent sliding time window in a frequency range of 30-130Hz in steps of four frequency bins was applied to enable improved frequency smoothing.

Equivalent to the ERF analysis, the significance of the difference between the garden-path conditions and their corresponding control conditions on the combined planar gradient data was established by using a nonparametric cluster randomisation test (Nichols and Holmes, 2002; E. Maris and R. Oostenveld, 2003) with 1000 randomisations (Montecarlo method).

In order to localize the neural sources of the power modulations in the different frequency bands, we applied an adaptive spatial filtering or beamforming technique (Dynamic Imaging of Coherent Sources, DICS) (Gross et al., 2001; Liljestrom et al., 2005). First, the individual MRI of every subject was coregistered with the subject's sensor space and then normalized to MNI-space (International Consortium for Brain Mapping Template; Montreal Neurological Institute, Montreal, Canada) to fit the template MRI. Subsequently a volume conduction model of the head (the so-called headmodel, i.e. the surface description of the brain) was constructed which was based on the individual subject's MRI. Then, a template grid based on a template MRI in MNI coordinates was divided into a regular 1 cm three-dimensional grid. Subsequently, we warped the individual subjects' MRI to fit the template MRI and the inverse warp was applied to the template grid. We then warped the grid back to fit the individual MRI to obtain a grid in MNI coordinates for every subject. This method has the advantage that specific grid points are located in the same area of the brain in all subjects in MNI space. As each recording block includes a specific gradiometer file containing the sensor positions for this specific run, we decided to compute the mean sensor positions across the recording blocks for the individual subject and applied this to the individual headmodels. In contrast to the lcmv-beamformer technique that we applied to the event-related fields, we did not use common filters, but applied the condition-specific filters to estimate the underlying sources as this appeared to model the sensor-level effects better. The LCMV source-analysis output was again subject to a nonparametric cluster randomisation test using a maximum cluster-level test statistic with 1000 randomisations.

### 5.6.3 TFR-Analysis: Results

The cluster randomisation revealed significant effects in theta (4-7Hz), alpha (10-14Hz), beta (14-26Hz), low gamma (30-60Hz), and high gamma (80-130Hz) for the garden-path conditions compared to the unambiguous control. The following paragraph describes the significant modulations of power separately for the different frequency bands of interest for the simple effects between the garden-path conditions and their respective control conditions. The simple effect 'load' between high-load garden-path and low-load garden-path did not return significant results (p>0.2).

### *5.6.3.1 Theta oscillations (4-7Hz)*

**Low-load garden-path condition compared to baseline condition:**

Consistent with previous studies that reported a frontal-parietal theta enhancement during Working Memory tasks (e.g. Jensen & Tesche, (2002)), we observed a bilaterally frontally distributed increase in theta power that was accompanied by a right-parietal theta enhancement (p=0.01 (*), time= 0.49 to 0.9). The activation over frontal sensor areas appeared to be more pronounced over the right hemisphere (see Fig. 40).

*Figure 40: A. Statistical map of the theta power increase (4-7Hz) on the sensor level for the low-load garden-path condition compared to the baseline condition. B. Raw-effect of the theta power increase for the difference between low-load garden-path condition and the baseline condition over representative frontal (top) and parietal (bottom) sensors.*
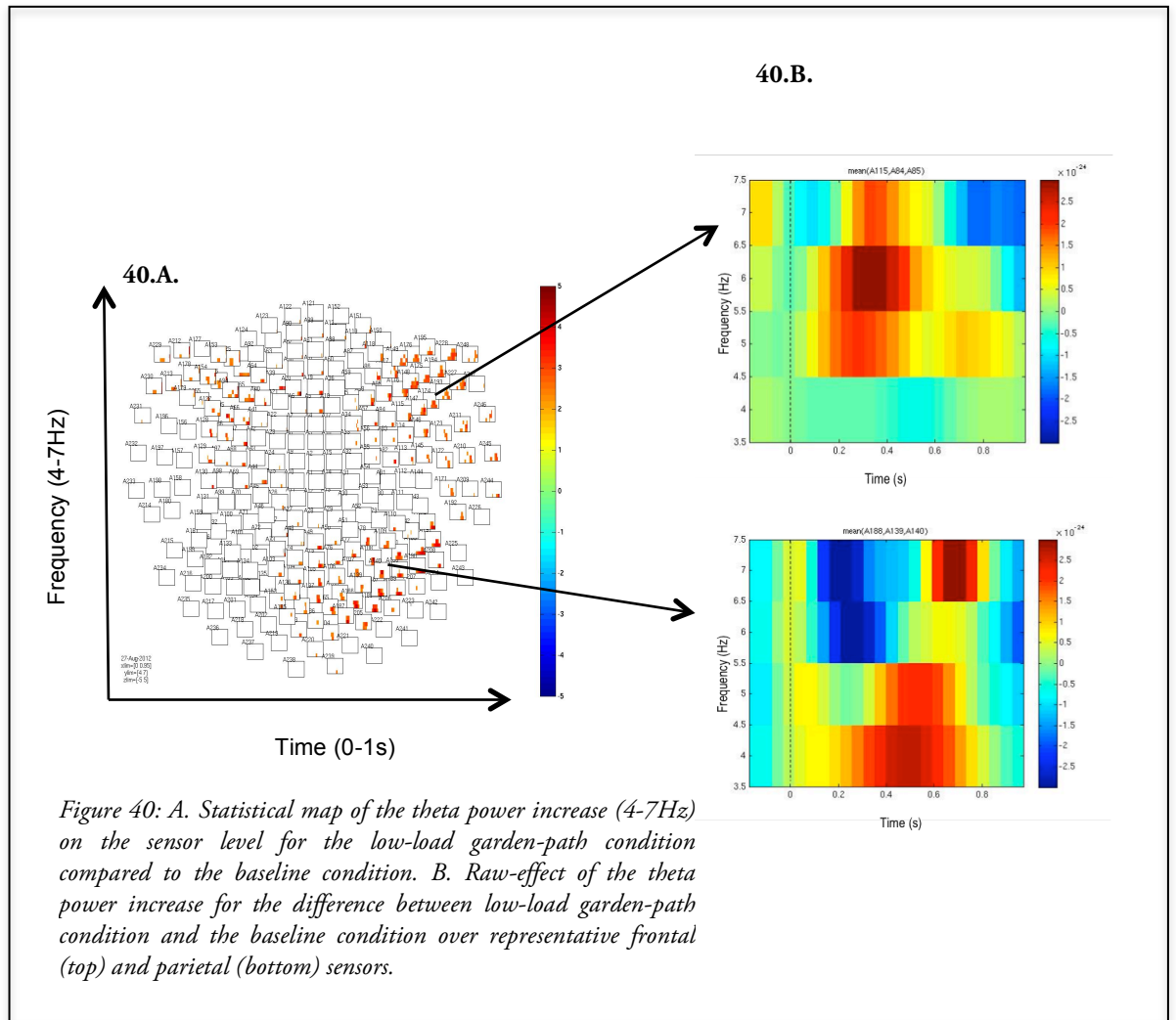
**High-load garden-path conditions compared to baseline:**

The non-parametric randomisation procedure revealed a late left-frontal-temporal increase in theta power which was accompanied by a weaker right-parietal theta power enhancement for the high-load garden-path condition compared to the control condition (p=0.02(*), time=0.45 to 0.84). In addition to this, we observed an increase of theta power over right parietal sensor areas. Surprisingly, the surface effect in the theta frequency band appeared to be less pronounced than the one observed in the low-load condition contrast (see Fig. 41).

*Figure 41: A. Statistical map of the theta power increase (4-7Hz) on the sensor level for the high-load garden-path condition compared to the baseline condition. B. Raw-effect of the theta power increase for the difference between high-load garden-path condition and the baseline condition over representative left-frontal (top) and left-parietal (bottom) sensors.*
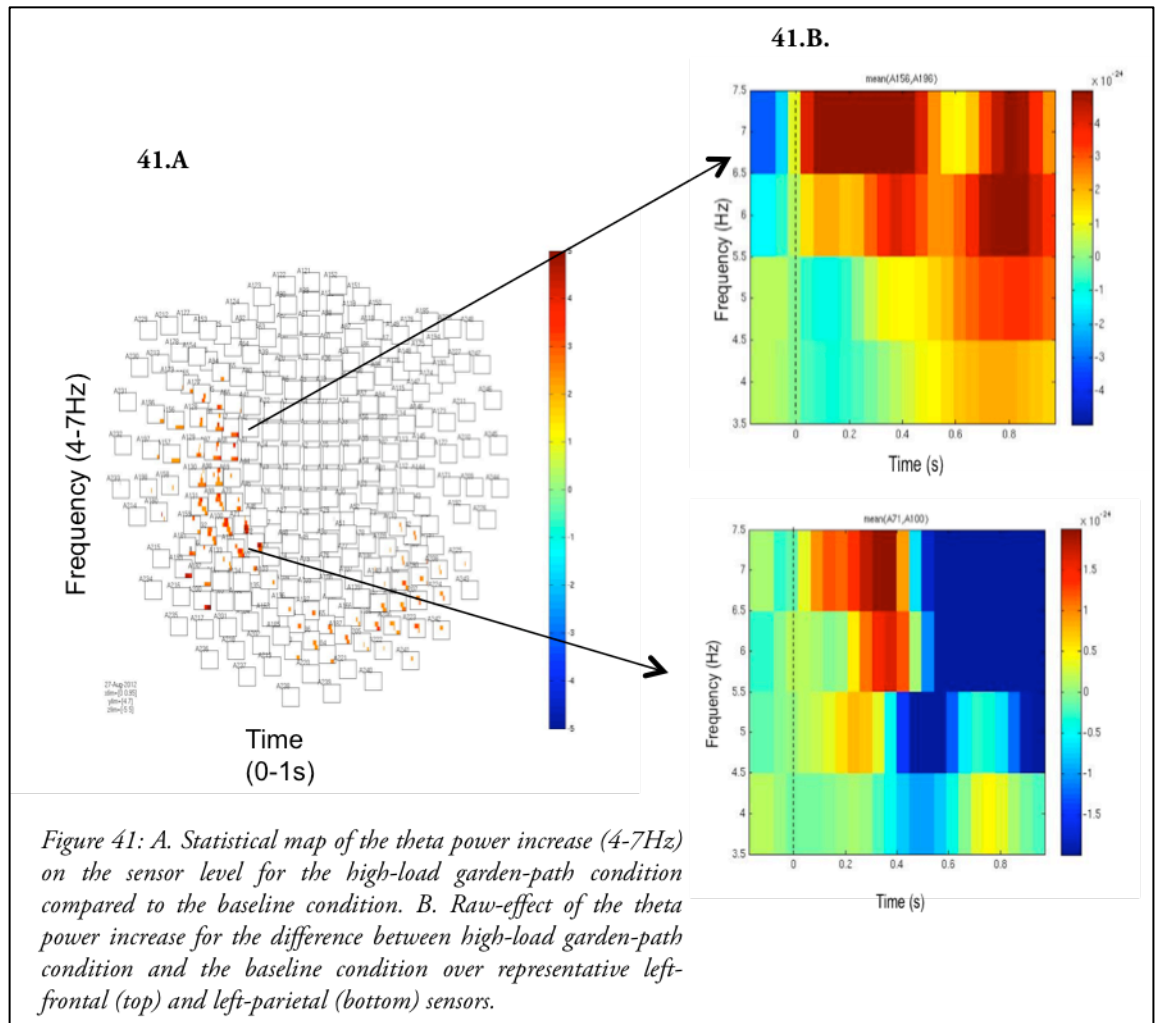
### 5.6.3.2 Alpha oscillations (8-14Hz)

**Low-load garden-path condition compared to baseline condition:**

Contrary to the results in the cataphora experiment (see Exp. 3), we did not find a decrease in power for the alpha frequency band, but an increase in power for the low-load garden-path condition compared to the baseline condition as represented by one positive cluster (p=0.0007(*)). This effect was located bilateral over anterior, midline, and temporal sensor areas and stronger pronounced over the left hemisphere. The alpha synchronization effect started shortly after the onset of the critical word "by" and lasted until 450ms after critical word onset (Fig. 42). Although the raw effect suggested also a desynchronization effect, this did not turn out significant, neither by splitting the

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frequency analysis into lower and upper alpha frequencies, nor by limiting the analysis to specific latencies (p>0.3 (n.s.)).
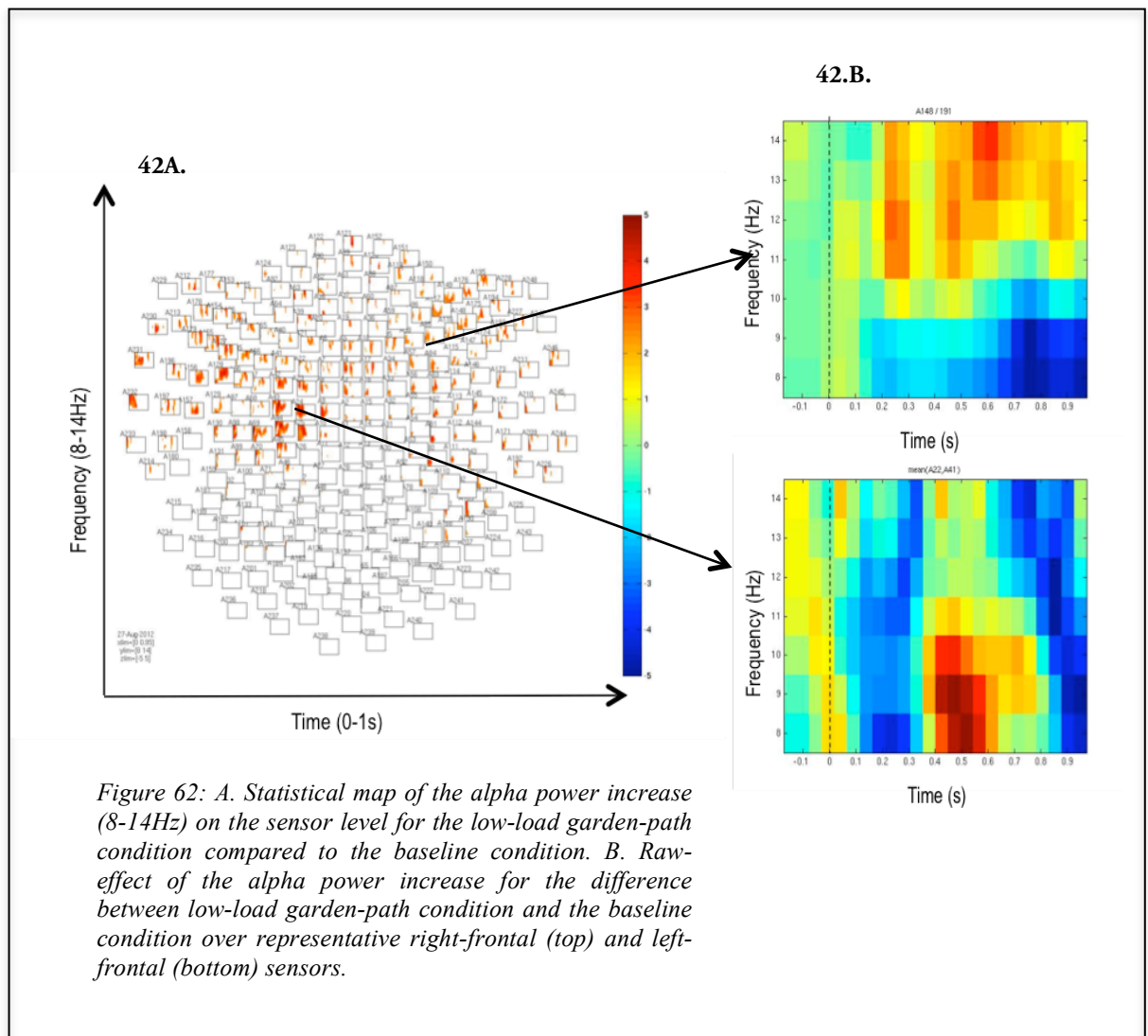


*Figure 62: A. Statistical map of the alpha power increase (8-14Hz) on the sensor level for the low-load garden-path condition compared to the baseline condition. B. Raw-effect of the alpha power increase for the difference between low-load garden-path condition and the baseline condition over representative right-frontal (top) and left-frontal (bottom) sensors.*

## High-load garden-path condition compared to baseline condition

The non-parametric randomisation test revealed a significant positive cluster in the alpha frequency range for the difference between the high-load garden-path condition compared to the baseline condition (p=0.006(*), time = 0 to 0.3s). The surface effect had a similar distribution as the alpha power enhancement that we observed for the low-load condition contrast, involving bilaterally frontal, temporal, and midline sensor areas.

In addition to this, there was an increase of alpha power over right parietal brain areas. The effect was strongest over left anterior and left temporal surface areas (see Fig. 43 below).



*Figure 43: A. Statistical map of the alpha power increase (8-14Hz) on the sensor level for the high-load garden-path condition compared to the baseline condition. B. Raw-effect of the alpha power increase for the difference between high-load garden-path condition and the baseline condition over representative left-frontal (top) and midline (bottom) sensors.*
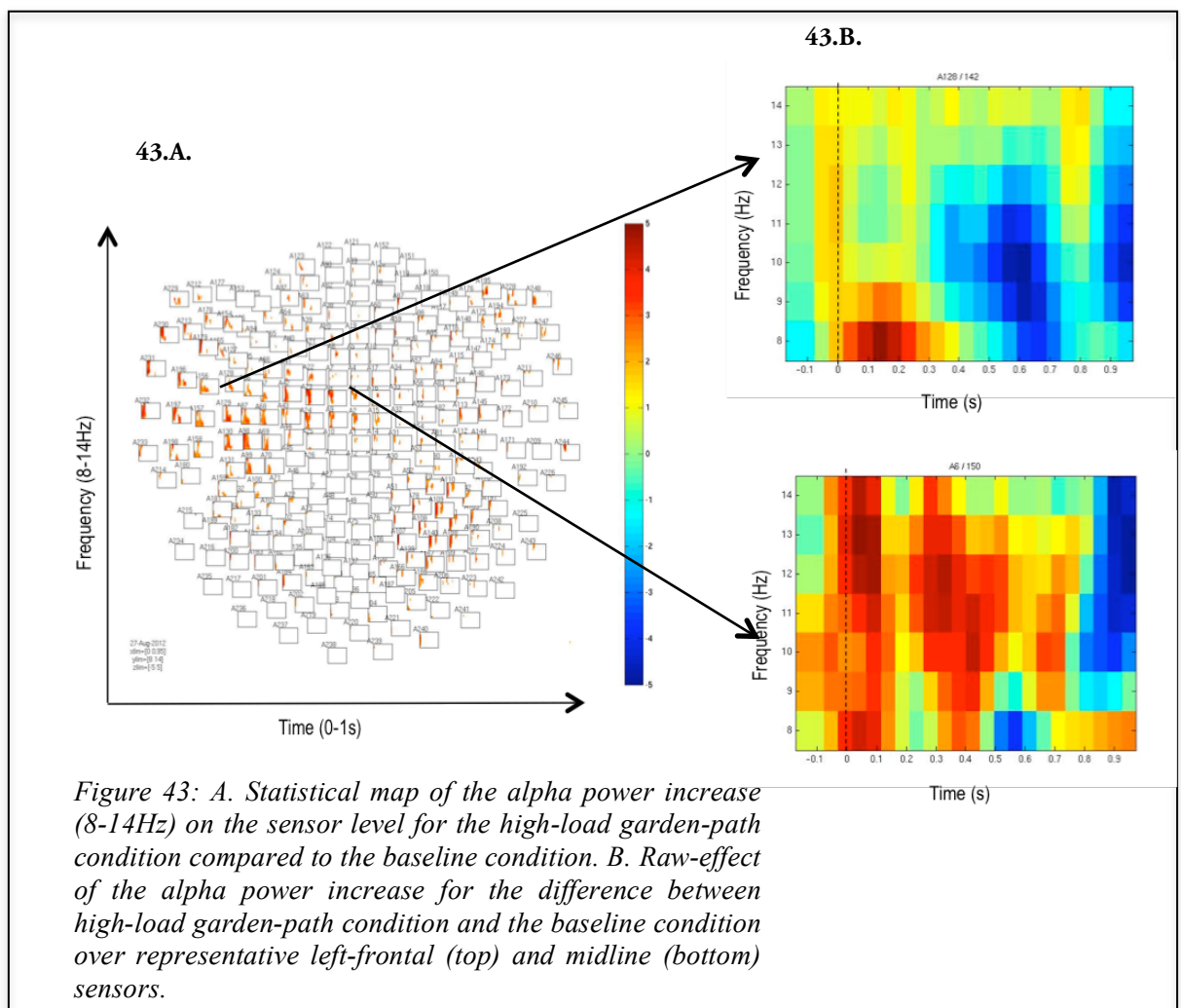
### *5.6.3.3 Beta oscillations (14-26Hz)*

**Low-load garden-path condition compared to baseline condition:**

Similar to the surface effects that we reported for the alpha frequency band, we found an increase of power for the beta frequency range: This effect involved a distributed network of bilateral frontal, midline, and left temporo-parietal surface areas (p=0.006, time= 0 to 0.34; see Fig. 44).



*Figure 44: A. Statistical map of the beta power increase (14-26Hz) on the sensor level for the low-load garden-path condition compared to the baseline condition. B. Raw-effect of the beta power increase for the difference between low-load garden-path condition and the baseline condition over representative left-midline (top) and left-parietal (bottom) sensors.*
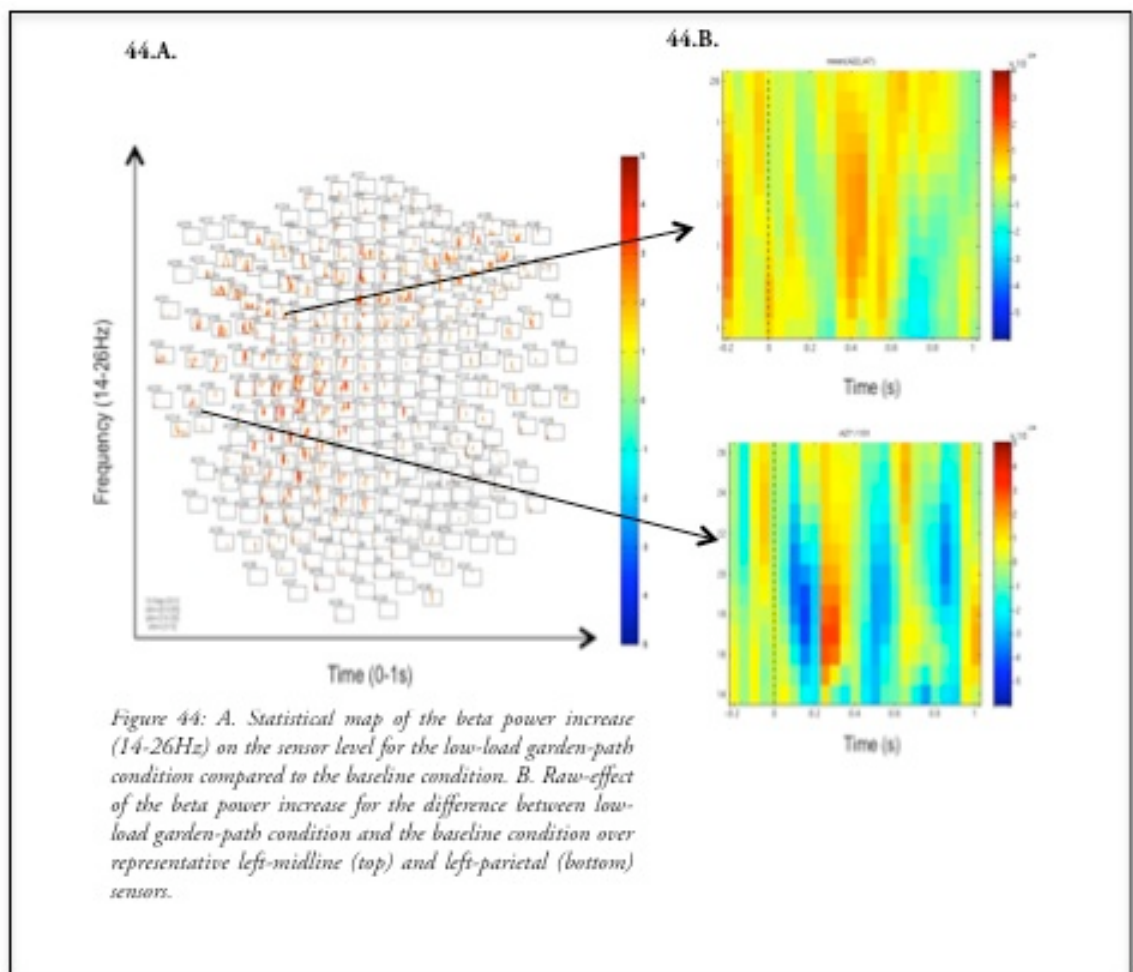
**High-load garden-path condition compared to baseline condition:**

The high-load condition contrast also induced a beta power enhancement over both hemispheres: We observed the strongest increase over left and right temporo-parietal sensor areas, while frontal areas showed a weaker increase in beta power than the above reported effect for the low-load condition contrast. This effect involved a distributed network of bilateral frontal, midline, and left temporo-parietal surface areas in a similar latency range as described for the low-load condition contrast (p=0.006, time=0 to 0.49) as depicted in Figure 45. Figure (45.A.) shows the statistical map for the masked significant effect on the sensor level and Figure (45.B.) depicts the raw-effect of the difference between high-load garden-path and baseline condition at representative frontal-midline (top) and left-parietal (bottom) sensors.



*Figure 45: A. Statistical map of the beta power increase (14-26Hz) on the sensor level for the high-load garden-path condition compared to the baseline condition. B. Raw-effect of the beta power increase for the difference between high-load garden-path condition and the baseline condition over representative left-midline (top) and left-parietal (bottom) sensors.*
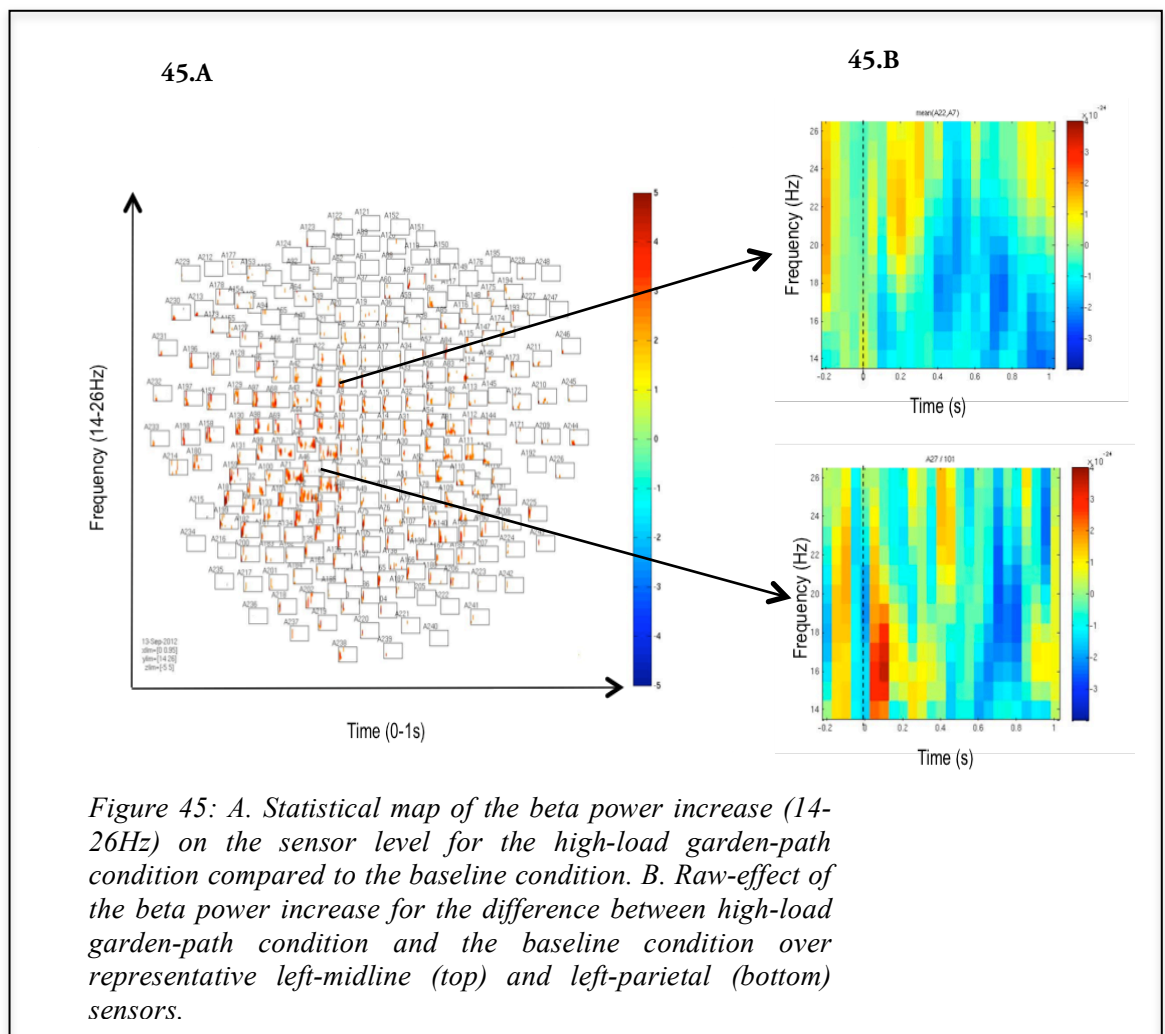
### 5.6.3.4 Gamma frequency (30-130Hz)

**High-load garden-path condition compared to baseline condition:**

Interestingly, only the comparison between the high-load garden-path conditions to the respective baseline conditions returned a significant effect in the gamma frequency range (p = 0.01(*)). The non-parametric randomisation test revealed an increase of gamma power in a latency window of 400ms to 1000ms after the critical word onset over left anterior and left-temporal sensor areas (see Fig. 46). This effect was made up of a transient and slightly earlier gamma band enhancement in the lower gamma band (around 45-70Hz), which was followed by a long-lasting increase in high gamma (between 90-110Hz).



Figure 46: A. Statistical map of the gamma power increase (30-130Hz) on the sensor level for the high-load garden-path condition compared to the baseline condition. B. Raw-effect of the beta power increase for the difference between high-load garden-path condition and the baseline condition over representative left-frontal (top) and left-temporal (bottom) sensors.
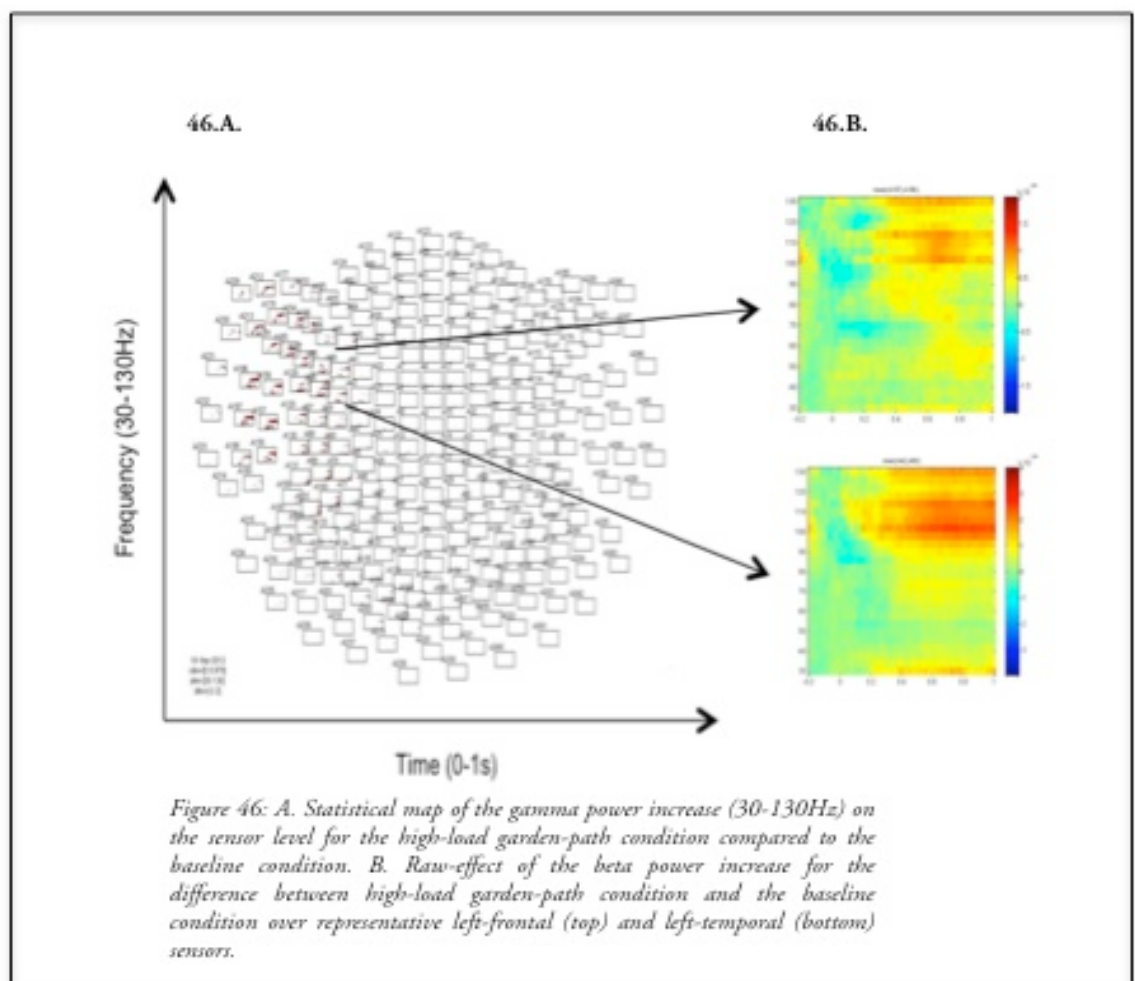
**5.6.4 Source Localization**

The section below will report the sources accounting for the modulations in the respective frequency bands for the simple effects garden-path condition (high-load / low-load) to their respective baseline condition. The simple effect 'load' (high-load garden-path vs. low-load garden-path) did not reach significance ($p>0.17$ (n.s.)). For a summary of the results of the source localization, please refer to table 4.

*5.6.4.1 Theta frequency (4-7Hz)*

For the source modelling of the sensor-level theta frequency effects we used a center frequency of 5Hz for the low-load condition contrasts (low-load gardenpath vs. baseline) and the same for the high-load condition contrast (high-load garden-path vs. baseline).

The sources accounting for the modulation in the theta band ($p=0.009(*)$) during the low-load garden-path condition versus the baseline condition comprised a distributed network with bilateral activation (see Fig. 47). The strongest modulation was found in the right parietal cortex (BA 40). In addition to this, we observed sources accounting for this theta power increase in the right inferior frontal lobe (BA 45), the anterior cingulate gyrus (BA 24, ACC), as well as the left superior temporal gyrus (BA 41, primary auditory cortex).
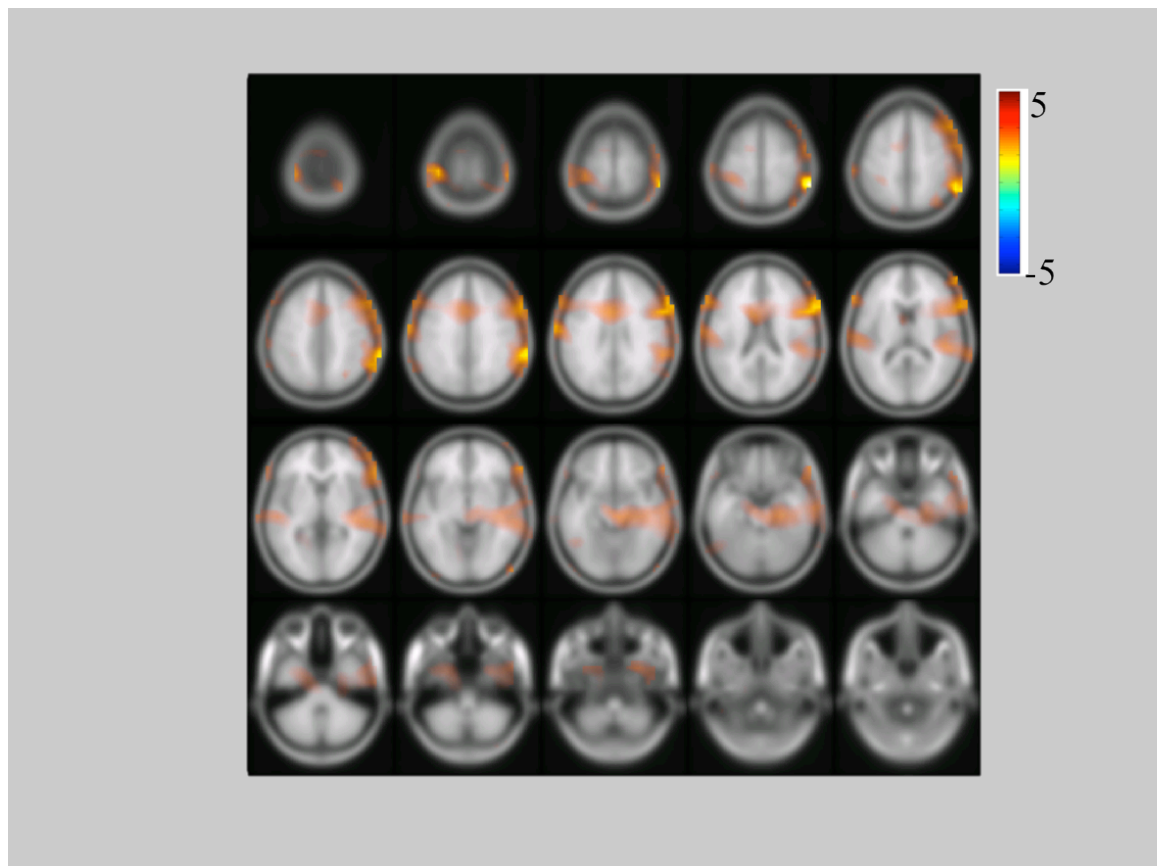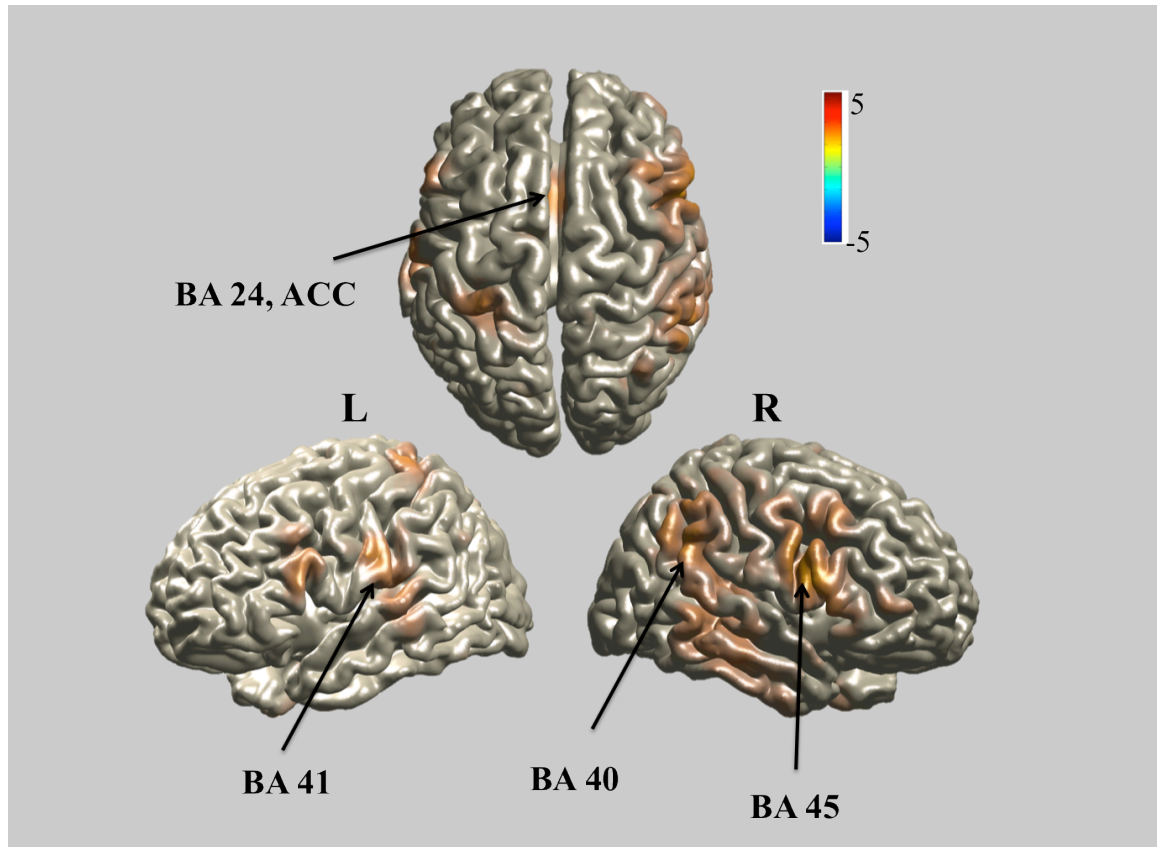
*Figure 47: Top: Projection of significant theta band sources for the main effect of low-load garden-path condition compared to control condition onto a surface brain comprising of a bilateral network with activation in the right inferior parietal lobe (BA 40), right inferior frontal gyrus (BA 45), left superior temporal gyrus, and anterior cingulate areas (BA 24). Bottom: 2D-slice visualisation of the significant sources.*

Similar to these effects we observed during the low-load garden-path processing the strongest modulation for the high-load garden-path condition compared to baseline condition in the bilaterally in the parietal lobes (BA 40) (p=0.009(*); see Fig. 48.A. and 48.B.). These effects were accompanied by a significant modulation in the anterior cingulate cortex (BA 24).
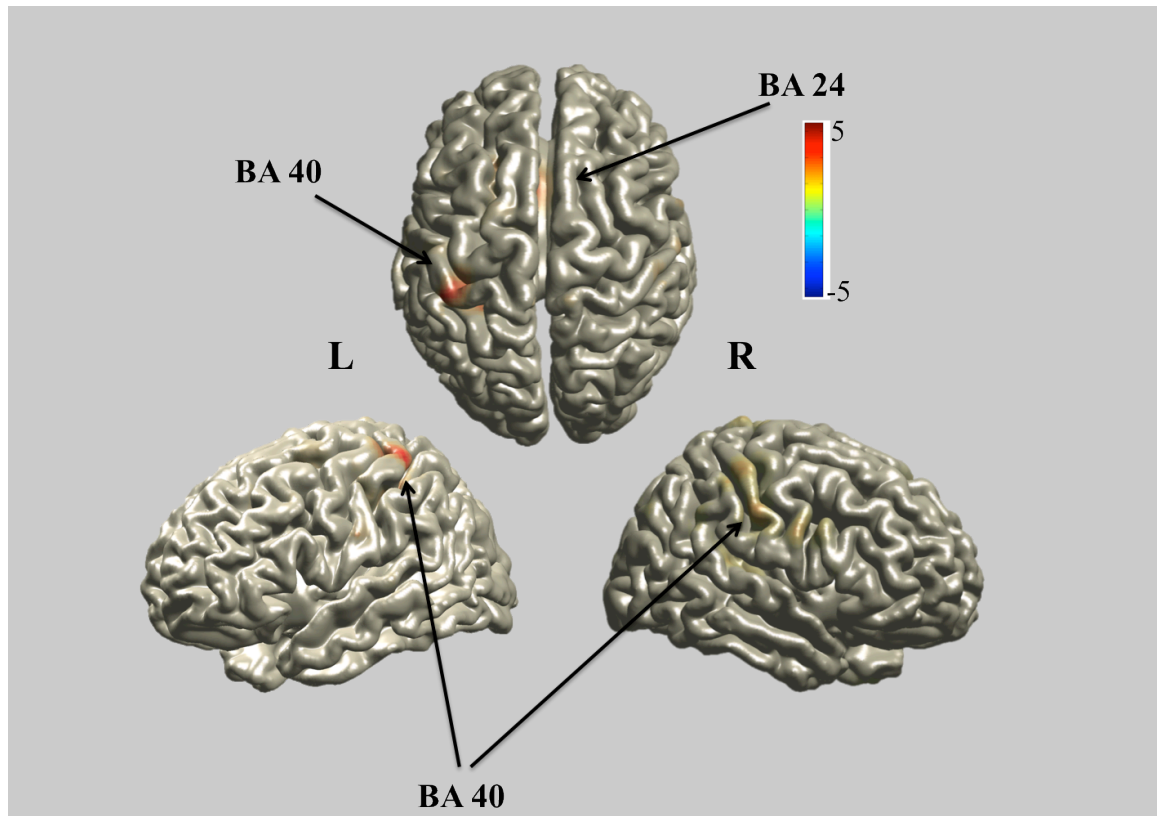


*Figure 78.A: Projection of significant theta band sources for the main effect of high-load garden-path conditions compared to control conditions onto a surface brain comprising of a network with activation in bilaterally in the inferior parietal lobe (BA 40) and anterior cingulate areas (BA 24).*
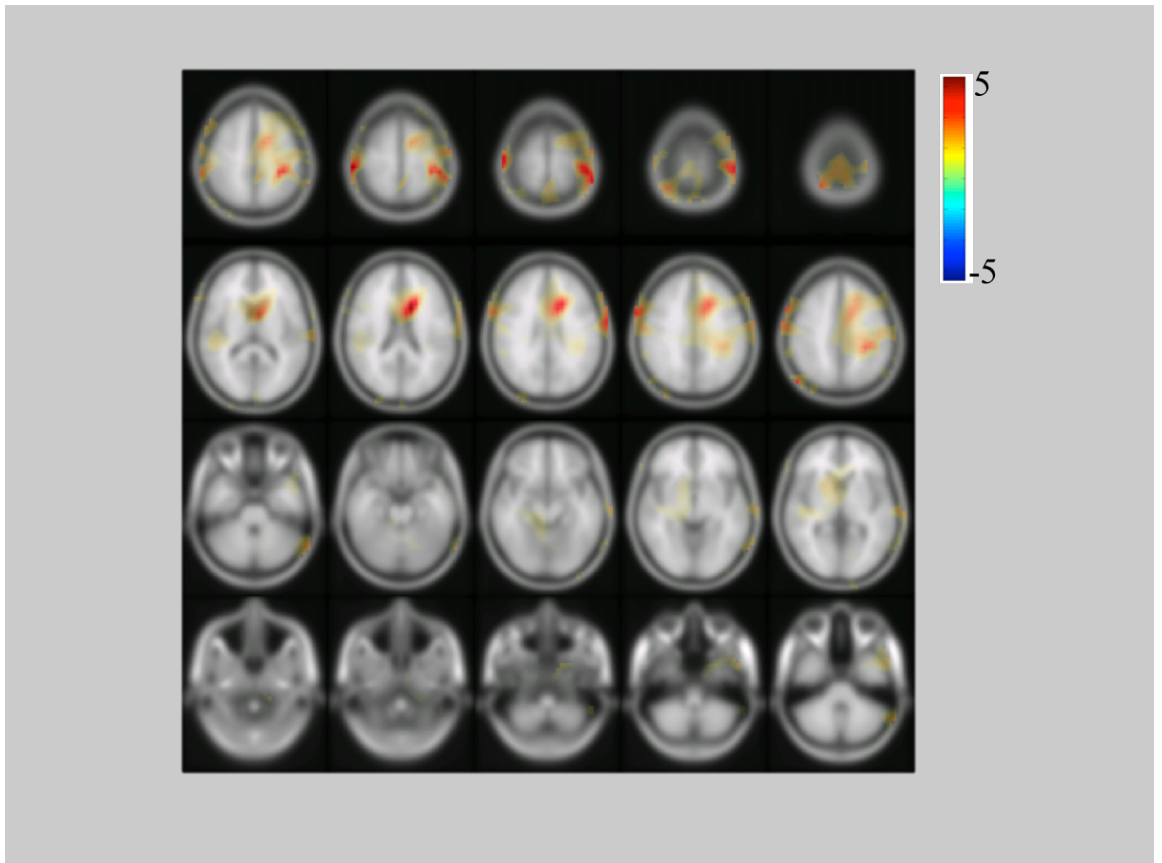
*Figure 48.B: 2D-slice visualisation of significant theta band sources for the main effect of high-load garden-path conditions compared to control conditions with activation in bilaterally in the inferior parietal lobe (BA 40) and anterior cingulate areas (BA 24).*

### 5.6.4.2 Alpha frequency (8-14Hz)

The DICS beamforming center frequency for the alpha band modulations was centered at 10Hz. The source accounting for the increase in alpha power for the low-load garden-path condition compared to the baseline condition is depicted in Figure 49. We localized the strongest activation in the left superior frontal lobe (BA 10; p=0.009(*))).
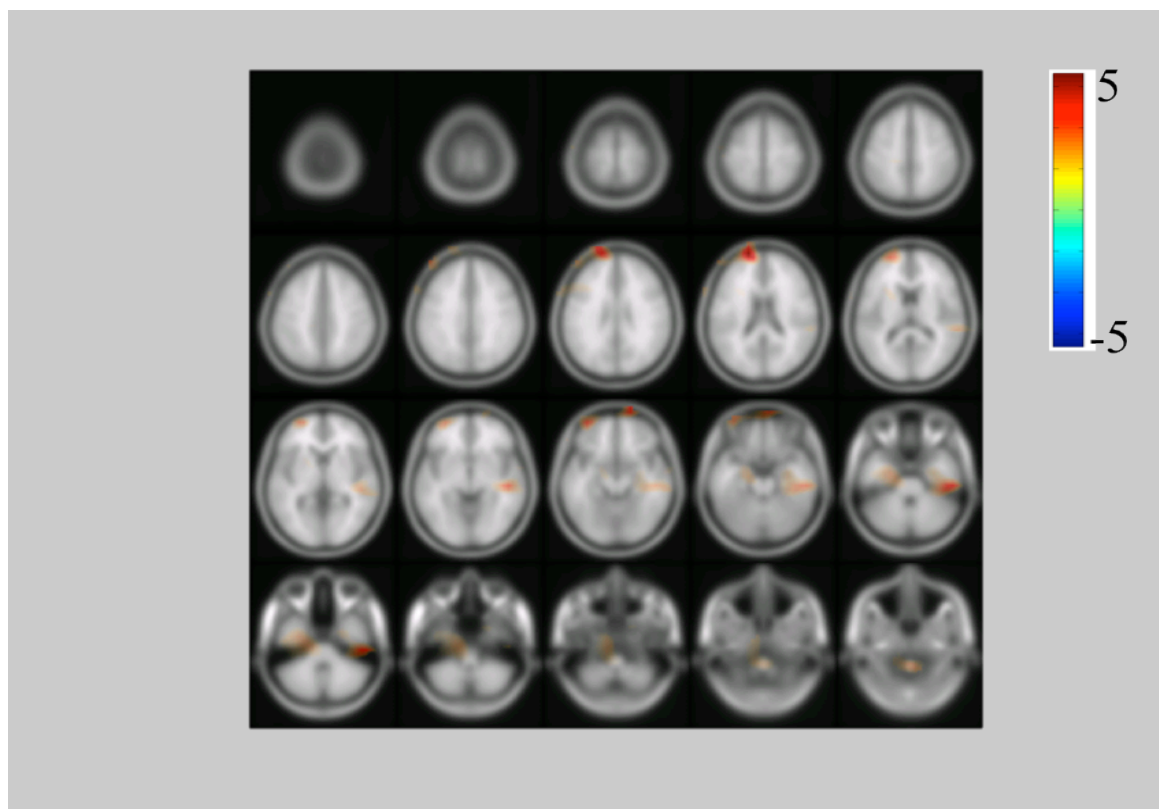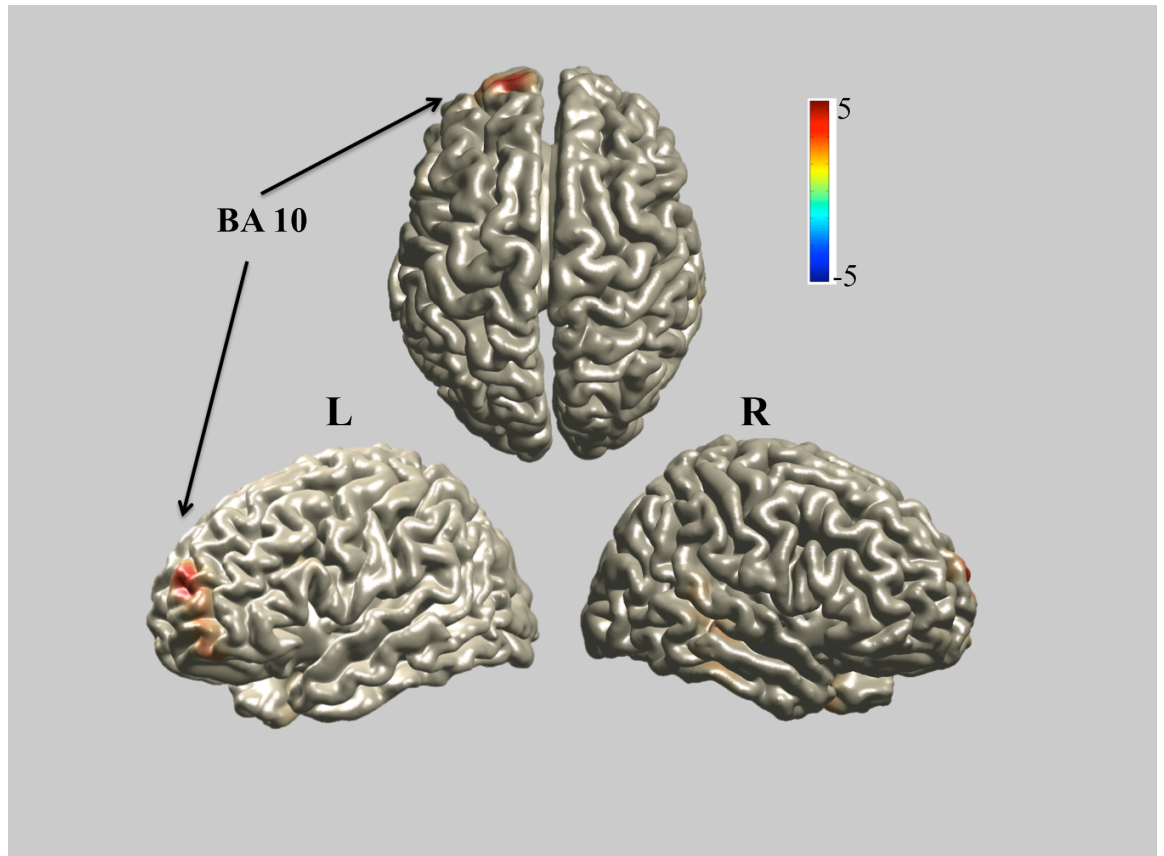
*Figure 49: Top: Projection of significant alpha band source for the main effect low-load garden-path conditions versus control conditions in the left superior frontal gyrus (BA 10). Bottom: 2D-slice visualisation of the significant alpha band effect.*

The alpha-band sources accounting for main effect of high-load garden-path conditions compared to the control conditions were located in the left superior frontal gyrus (BA 8), the left cingulate gyrus (BA 31), the left precentral gyrus (BA 4), and the right temporal lobe (BA 41) (p=0.009(*); see Fig. 50.A. and Fig. 50.B.). While the main effect of low-load conditions versus control conditions for the alpha band sources appeared to involve strongly localized brain areas (BA 10), the main effect main effect of the high-load garden-path conditions compared to the control conditions manifested itself in distributed sources mostly confined to left hemisphere regions, but also weaker activation in the right temporal lobe (BA 41).
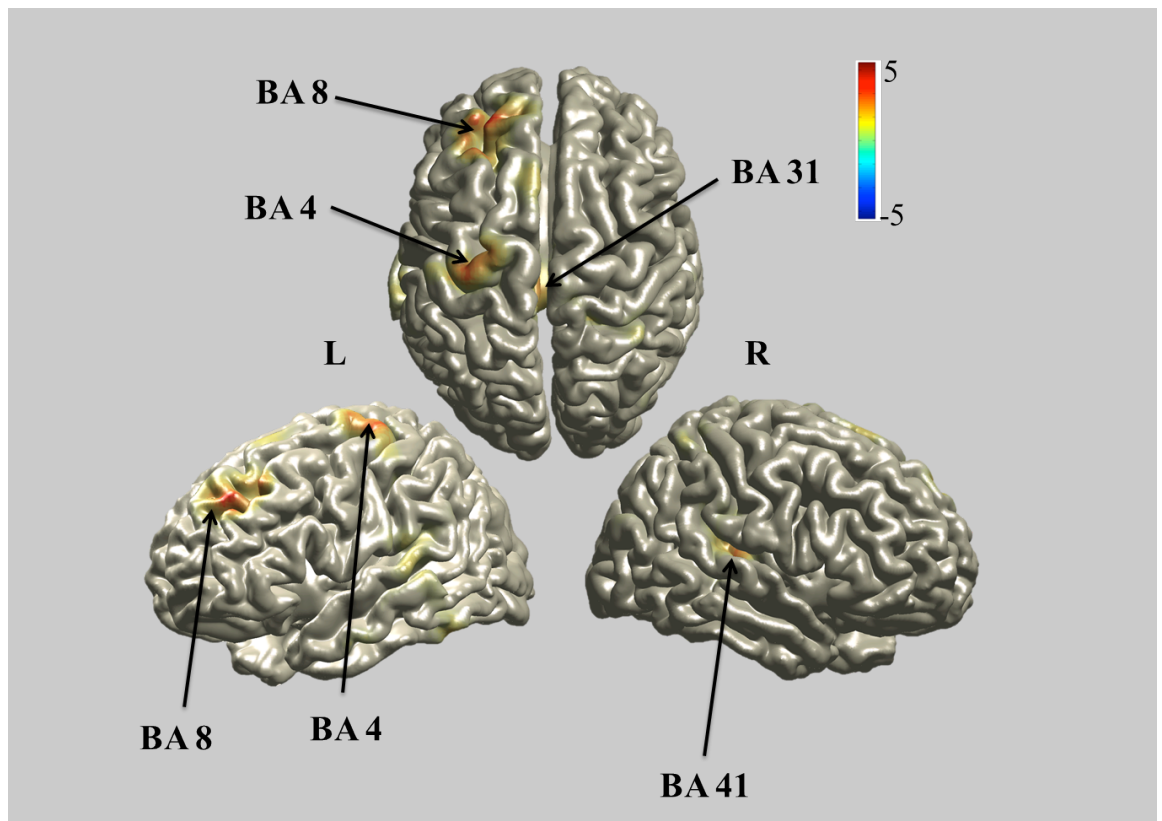


*Figure 80.A: Surface projection of significant alpha band sources for the main effect high-load garden-path conditions versus control conditions in left superior frontal gyrus (BA 8), left posterior cingulate gyrus (BA 31), left precentral gyrus (BA 4), and right temporal lobe (BA 41).*
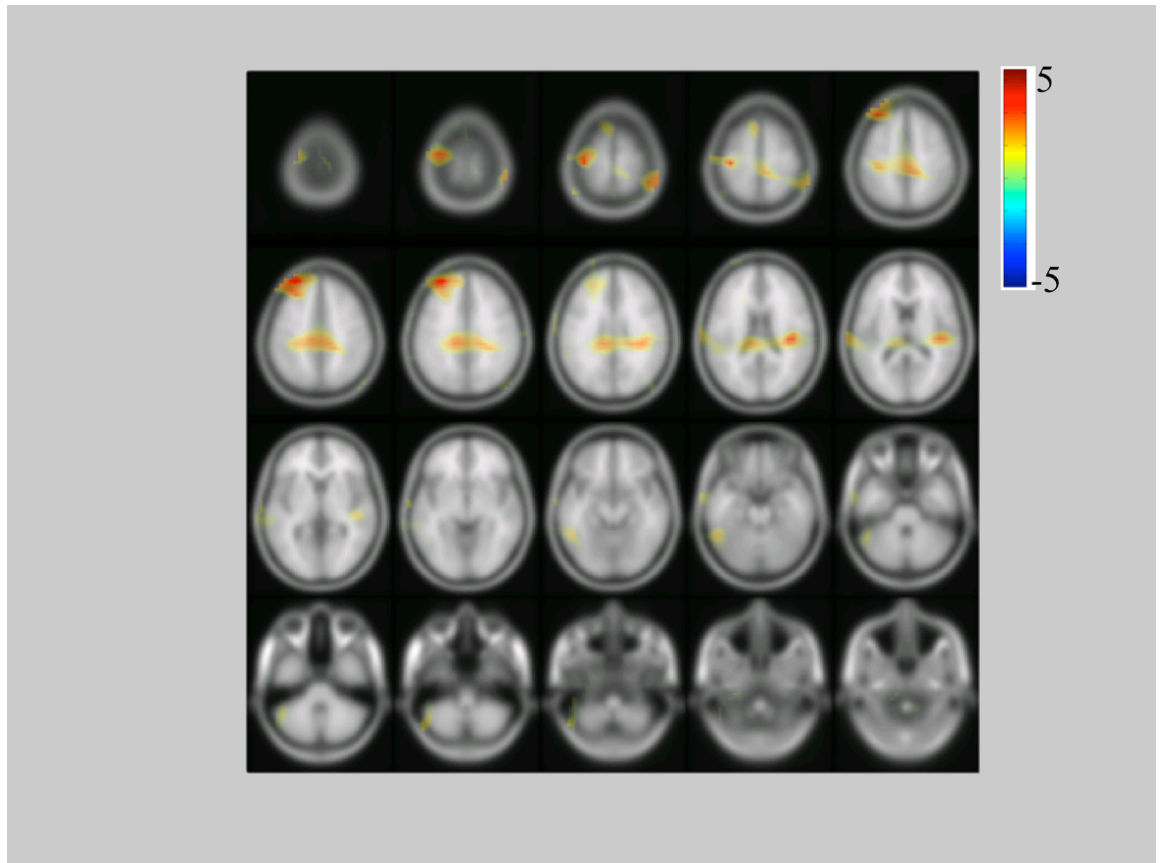
*Figure 50.B: 2D-slice projection of significant alpha band sources for the main effect high-load garden-path conditions versus control conditions in left superior frontal gyrus (BA 8), left posterior cingulate gyrus (BA 31), left precentral gyrus (BA 4), and right temporal lobe (BA 41).*

### 5.6.4.3 Beta Frequency (14-26Hz)

We used a center frequency of 20Hz for the DICS beamforming technique in the beta frequency range. As depicted in Figure 51, the source accounting for the beta modulation in the low-load condition contrast localized in the left parietal lobe (BA 3; $p=0.008(*)$).
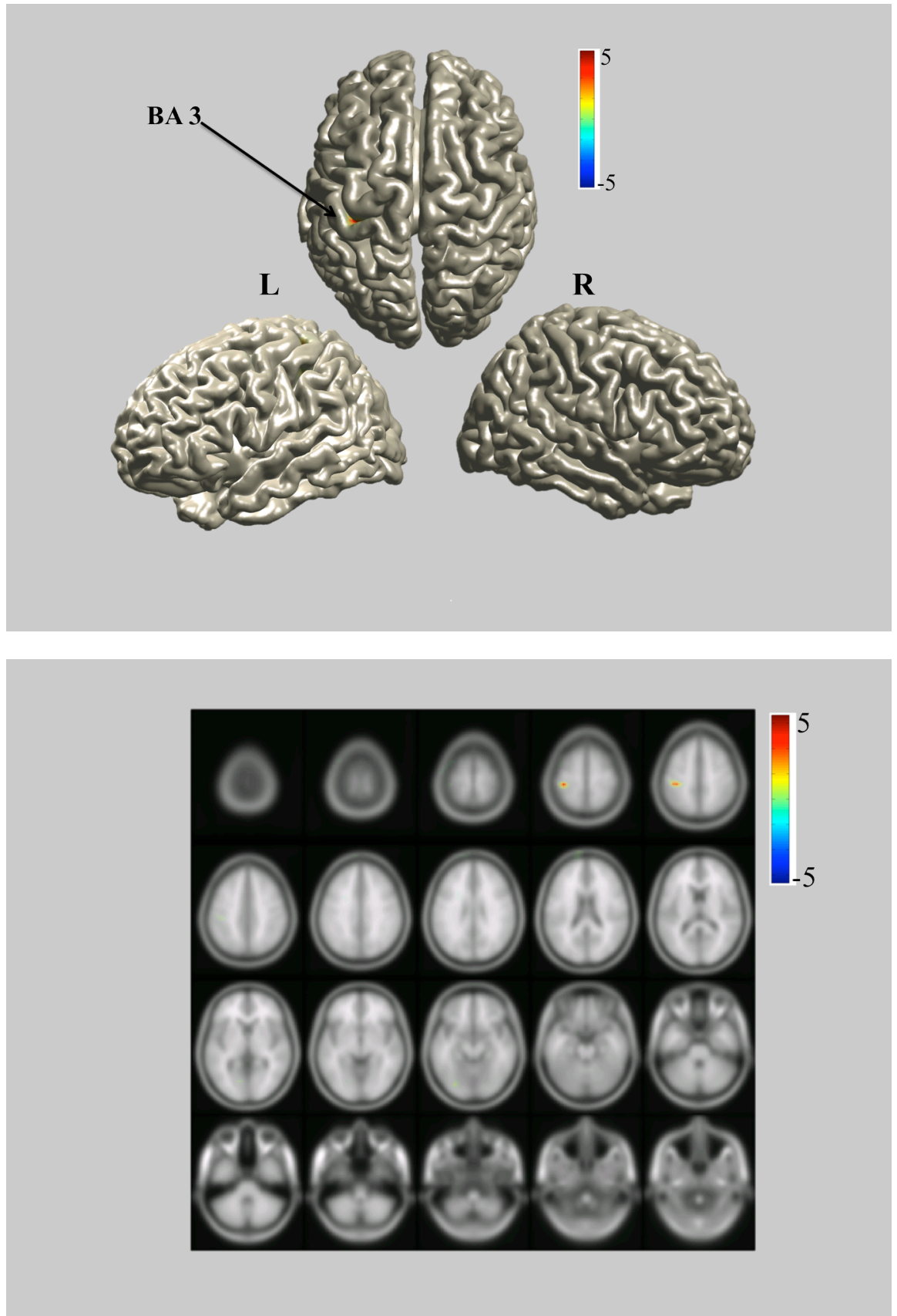
*Figure 51: Top: Surface projection of significant beta band source for the main effect low-load garden-path conditions versus control conditions in left parietal lobe (BA 3). Bottom: 2D-slice visualisation of the beta band effect.*

Contrary to that, the beamforming approach identified three beta-band sources for the main effect high-load garden-path conditions compared to the baseline condition (see Figure 52.A and Figure 52.B): The strongest activation localized in the right frontal lobe (p=0.009(*)), or more precisely, the medial frontal gyrus (BA 10). Additional sources accounting for this effect were the left superior temporal gyrus (BA 22) and the right occipital lobe (BA 31).
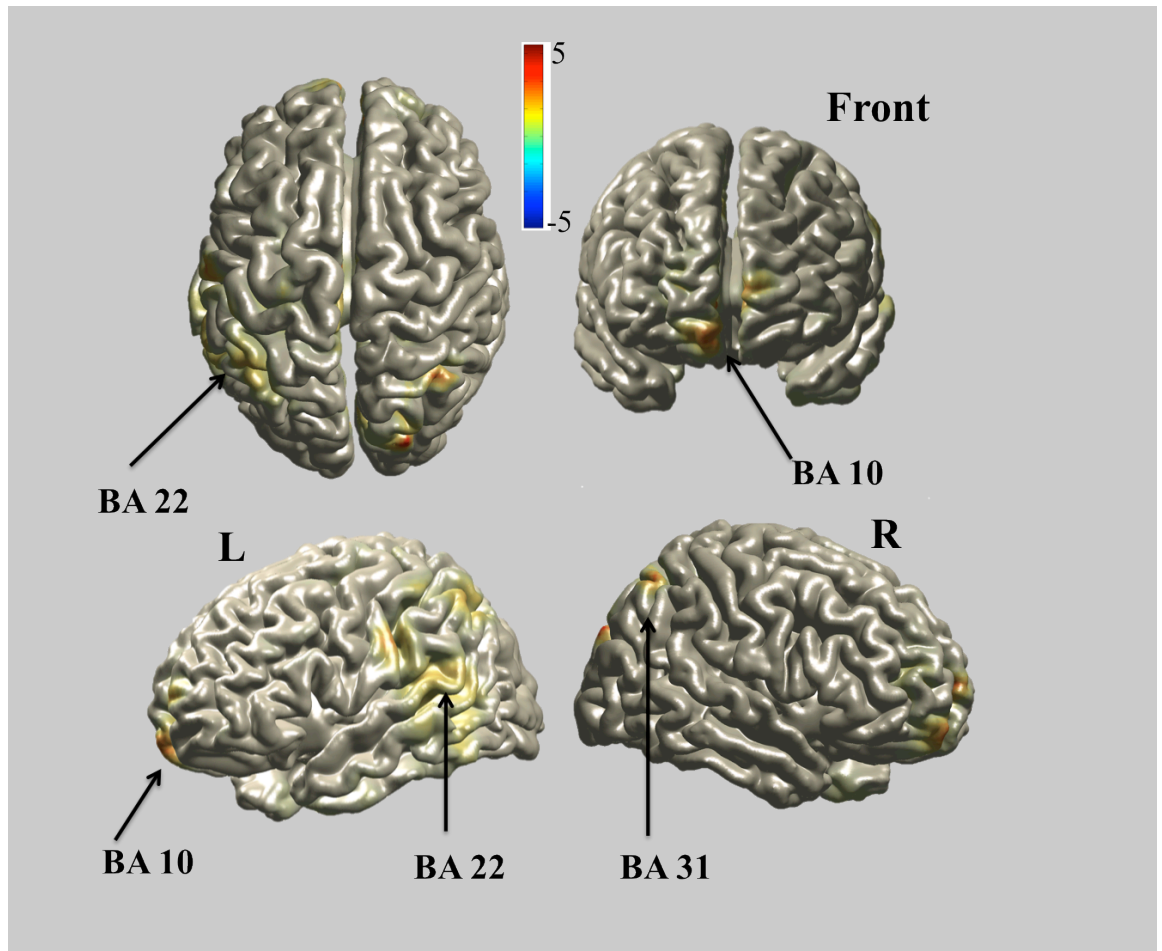


*Figure 52.A: Surface projection of significant beta band sources for the main effect high-load garden-path conditions versus control conditions in right medial frontal gyrus (BA 10), left superior temporal gyrus (BA 22), and right occipital lobe (BA 31).*
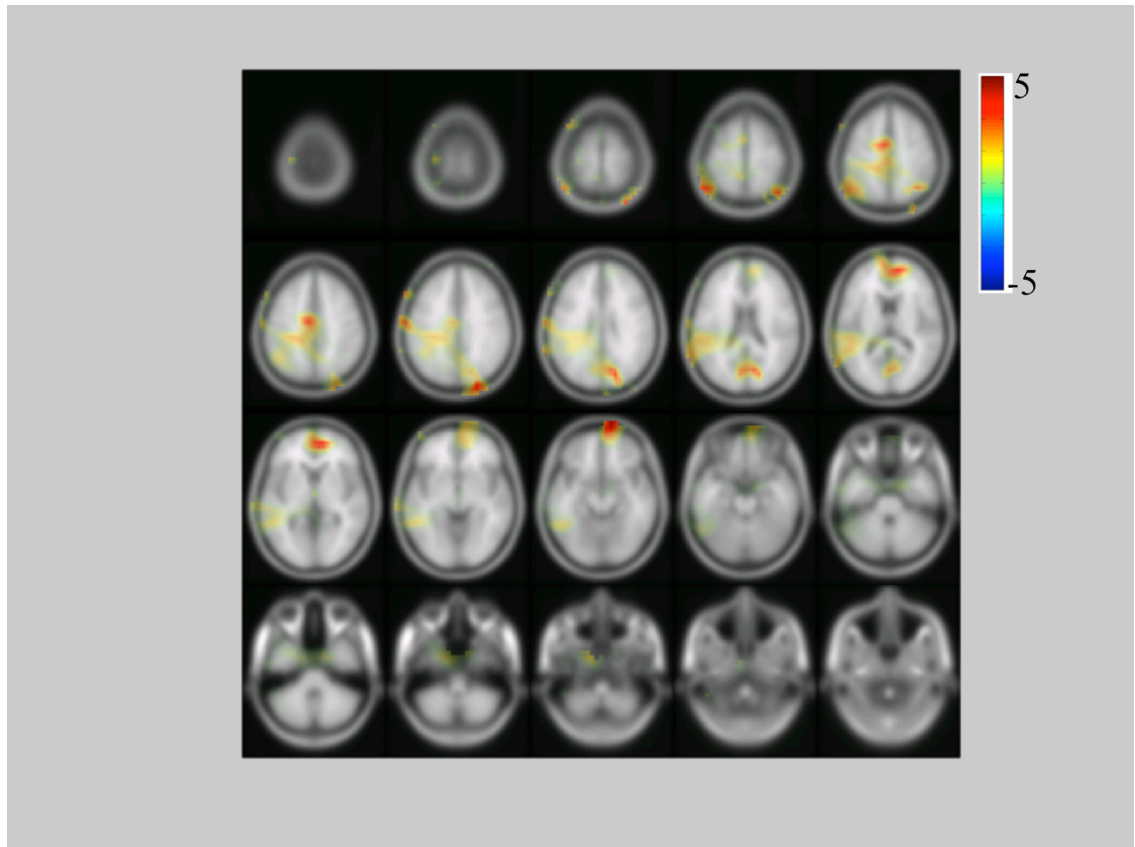
*Figure 52.B: 2D-slice visualisation of significant beta band sources for the main effect high-load garden-path conditions versus control conditions in right medial frontal gyrus (BA 10), left superior temporal gyrus (BA 22), and right occipital lobe (BA 31).*

### 5.6.4.4 Gamma Frequency (30-130Hz)

Only the comparison of high-load garden-path conditions versus baseline showed modulations of gamma band frequency in the sensor-level analysis. As described before, we observed a transient effect in the lower gamma frequency range and a long lasting increase of power in the higher gamma frequency band between 400-1000ms after critical word onset. To localize the sources that account for these effects we conducted two analyses: For the lower gamma band effect we centered the DICS beamformer around 40Hz while we chose for the high gamma effect a center frequency of 100Hz. The source accounting for the modulation in the lower gamma band was the posterior part of the left superior frontal gyrus (BA 6), the right inferior parietal lobe (BA 40), and the left cerebellum (see Figure 53).
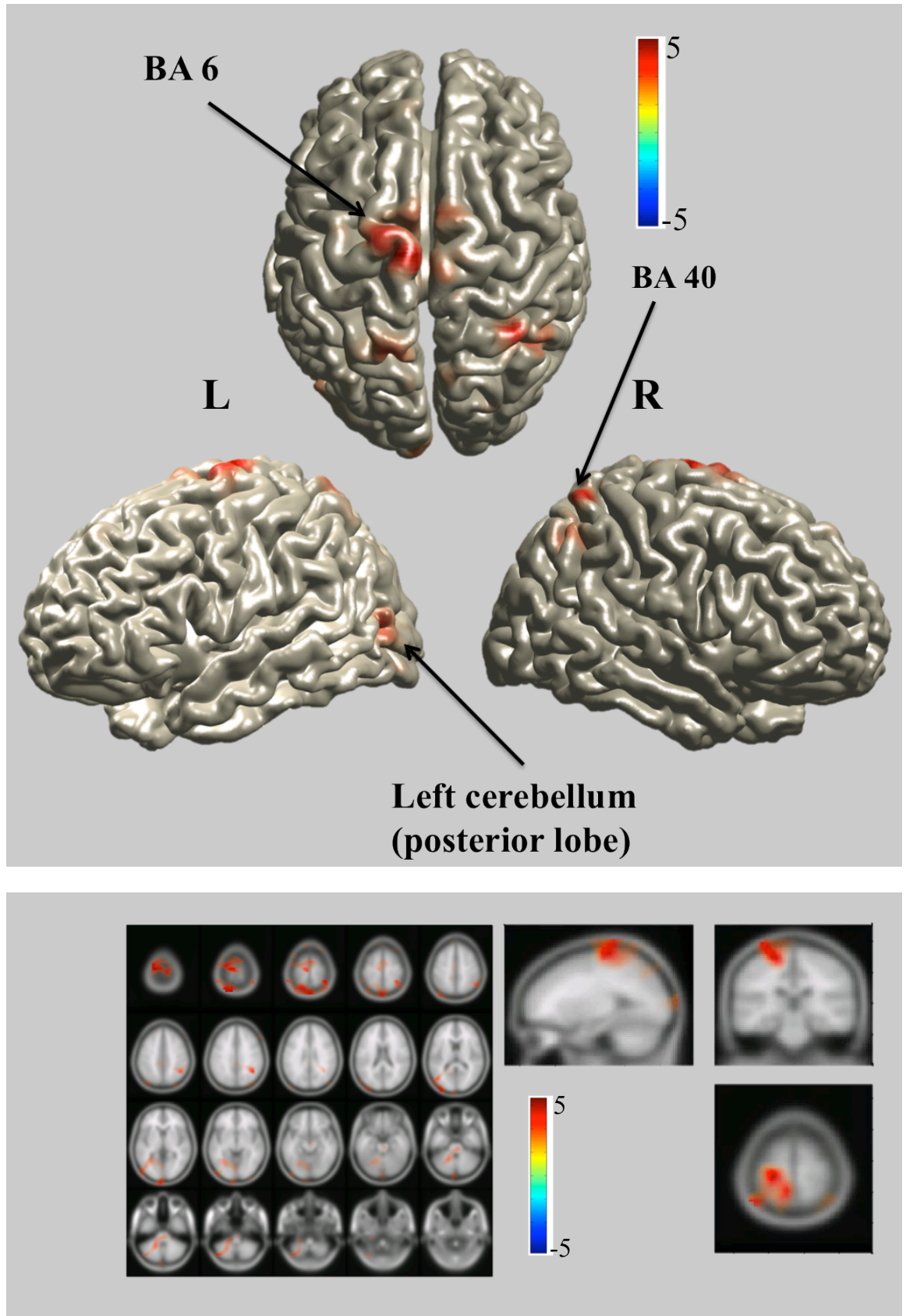
*Figure 53: Top: Surface projection of significant low gamma band sources for the main effect high-load garden-path conditions versus control conditions in right superior frontal gyrus (BA 6), right inferior parietal lobe (BA 40), and left cerebellum. Bottom: 2D-slice visualisation of the low gamma band sources.*

Although the surface effect of the higher gamma band activity suggested a rather anterior source, the source accounting for this modulation localized in the posterior parts of the left frontal lobe (p=0.009(*)) – the precentral gyrus (BA 4; see Figure 54)).
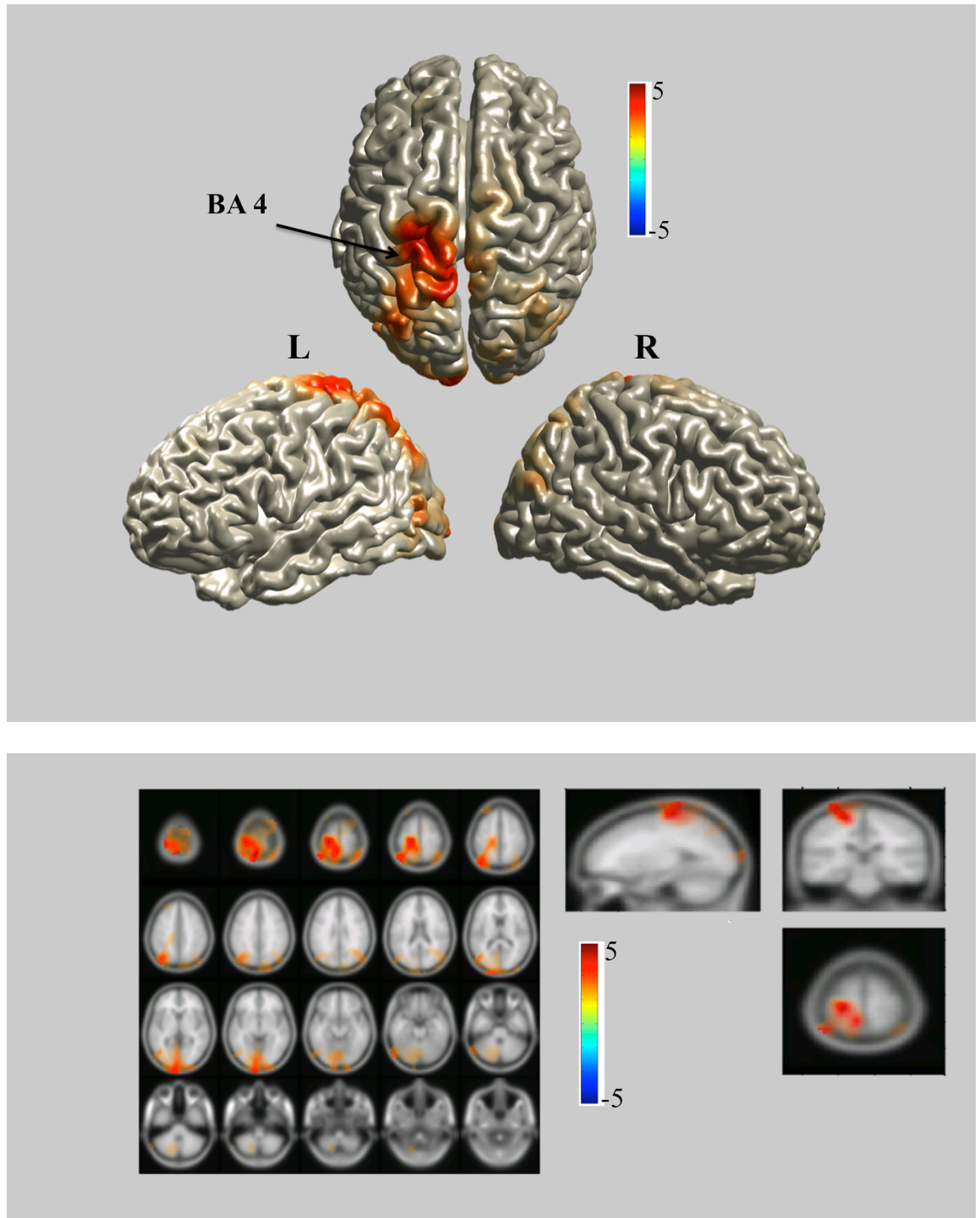


*Figure 54: Top: Surface projection of significant high gamma band sources for the main effect high-load garden-path conditions versus control conditions in left frontal lobe, precentral gyrus (BA 4). Bottom: 2D-slice visualisation of the high gamma band sources.*

| Contrast | Frequency | Activation peak | BA | Significance (*) | x   y   z | Range |
|---|---|---|---|---|---|---|
| Low-load GP vs. Baseline | Theta (5Hz) | Right Cerebrum, Parietal Lobe, Inferior Parietal Lobule | 40 | p=0.009(*)) | (54, -48, 58) | 4 |
| | | Right Cerebrum, Frontal Lobe, Inferior Frontal Gyrus, | 45 | | (62, 16, 20) | 0 |
| | | Left Cerebrum, Temporal Lobe, Superior Temporal Gyrus | 41 | | (-56, -24, 8) | 2 |
| | | Left Cerebrum, Limbic Lobe, Cingulate Gyrus, | 24 | | (-2, 14, 28) | 0 |
| High-load GP vs. Baseline | Theta (5Hz) | Left Cerebrum, Parietal Lobe, Postcentral Gyrus | 40 | p = 0.009(*)) | (-36, -34, 54) | 0 |
| | | Left Cerebrum, Limbic Lobe, Anterior Cingulate | 24 | | (-12, 16, 22) | 4 |
| | | Right Cerebrum, Parietal Lobe, Inferior Parietal Lobule | 40 | | (54, -48, 58) | 4 |
| Low-load GP vs. Baseline | Alpha (10Hz) | Left Cerebrum, Frontal Lobe, Superior Frontal Gyrus | 10 | p=0.009(*) | (-18, 66, 22) | 2 |
| High-load GP vs. Baseline | Alpha (10Hz) | Left Cerebrum, Frontal Lobe, Superior Frontal Gyrus | 8 | p=0.009(*) | (-30, 48, 40) | 2 |
| | | Left Cerebrum, Limbic Lobe, Cingulate Gyrus | 31 | | (-12, -26, 40) | 0 |
| | | Left Cerebrum, Frontal Lobe, Precentral Gyrus | 4 | | (-34, -22, 62) | 0 |
| | | Right Cerebrum, Temporal Lobe, Transverse Temporal Gyrus | 41 | | (42, -24, 14) | 1 |
| Low-load GP vs. Baseline | Beta (20Hz) | Left Cerebrum, Parietal Lobe, Postcentral Gyrus | 3 | p=0.008(*)) | (-36, -30, 58) | 0 |
| High-load GP vs. Baseline | Beta (20Hz) | Right Cerebrum, Frontal Lobe, Medial Frontal Gyrus | 10 | p=0.009(*)) | (6, 52, 6) | 1 |
| | | Left Cerebrum, Temporal Lobe, Superior Temporal Gyrus | 22 | | (-58, -38, 18) | 1 |
| | | Right Cerebrum, Occipital Lobe, Precuneus | 31 | | (12, -72, 26) | 0 |
| High-load GP vs. Baseline | Gamma low (40Hz) | Left Cerebrum, Frontal Lobe, Superior Frontal Gyrus | 6 | p=0.009 (*) | (-10, -14, 72) | 5 |
| | | Right Cerebrum, Parietal Lobe, Inferior Parietal Lobule | 40 | | (40, -50, 36) | 2 |
| | | Left Cerebellum, Posterior Lobe, Cerebellar Tonsil | | | (-20, -52, 36) | 0 |
| High-load GP vs. Baseline | Gamma high (100Hz) | Left Cerebrum, Frontal Lobe, Precentral Gyrus | | p=0.009 (*) | (-26, -26, 68) | 1 |

*Table 4: Summary of the results of the functional localization for the different frequency band modulations*

## 5.7 Summary & Discussion

In the present MEG study we investigated event-related fields and the role of oscillatory activity associated with cognitive load in response to more or less syntactically complex garden-path sentences. The ERF analysis identified similar components for both, the low-load condition contrast and the high-load condition contrast. In line with studies investigating the neurocognitive correlates of working memory load due to syntactic complexity (e.g. Kaan, 2002; Fiebach et al., 2001), this was reflected in sustained anterior that co-occurred with temporo-parietal negativities, but no late positivity was observed. Although both condition contrasts showed comparable effects, the sensor-level analysis suggested (in line with our expectations) that the effect was more pronounced in the high-load garden-path condition compared to the baseline condition than the analogue low-load condition contrast:

The non-parametric randomisation test identified a significantly stronger left-anterior negativity for the high-load garden-path condition compared to the low-load garden-path condition. Subsequently, we applied a source localization technique to determine the sources accounting for the ERF sensor-level effects. The majority of neuropsychological studies suggest that the prefrontal cortex substantially contributes to Working Memory as well as long-term memory (e.g. Shimamura, 1995; Ranganath & Knight, 2003). In line with this, most studies on syntactic complexity reported activation in the inferior frontal gyrus, particularly BA 45 and BA 44, but also in more anterior regions such as BA 47 (see Friederici 2011).

It has been suggested that the localization of the syntactic complexity effect is reflected in more activation for complex than simple sentences, and strongly depends on the specific experimental demands at hand. In our experiment we observed that the simple effects between the garden-path condition (high-load / low-load) and their respective unambiguous control conditions was reflected in differential sources: The non-parametric test identified the sources accounting for the negativities during the

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reading of the low-load garden-path conditions bilaterally in the superior temporal gyri (BA 22) and the left middle frontal gyrus (BA 6). BA 22 has been shown to be bilaterally activated during the processing of sentential phrases (Price, 2000; Braun et al., 2001; Indefrey & Levelt, 2004; Stowe et al., 2005) while BA 6 has been shown to be activated by syntactic error processing. More importantly, some studies have reported activation in premotor areas such as BA 6 during the processing of syntactically complex sentences (e.g., Stowe, Paans, Wijers, & Zwarts, 2004; see Christensen, 2008, 2010; Stowe, Haverkort, & Zwarts, 2005, for overviews). By contrast the source accounting for the anterior negativity during the high-load garden-path processing localized in the left dorso-lateral prefrontal cortex (BA 9). Brodmann area 6, 8, and 9 mostly respond when it is necessary to constantly update working memory or when memory for the temporal order must be maintained. Furthermore, the dorsolateral prefrontal cortex has been shown to be recruited in situations where tasks require the organization of items that are active in Working Memory (e.g. D'Esposito et al., 1999; Petrides, 2000; Blumenfeld & Ranganath, 2006).

The simple effect 'load' for the comparison between the high-load garden-path condition and the low-load garden-path condition identified BA 45, an area generally associated with the processing of syntactically complex sentences, as source accounting for the left-anterior modulation between these conditions in the ERF-profile. Subsequently we tried to disentangle the contributions of the main effect 'ambiguity' versus the main effect 'load' towards the observed effects. The analysis uncovered distinct source activation for the two main effects: While the main effect 'load' (analogue to the simple effect 'load') activated BA 45, the main effect 'ambiguity' was localized in areas associated with domain-general executive function, namely the right ventro-lateral prefrontal region BA 47 and the left-lateral BA 6. This replicates the results of Experiment 1, where we also found activation in BA 6 during the processing of 'un-

embedded' syntactic garden-path sentences at the earliest point of disambiguation (more precisely, for the *exact* same sentence type).

There have been considerable discussions during the last decades whether there is a functional specialization of BA 45 (*Broca's area*) for syntactic working memory and syntactic representations itself, or whether BA 45 may be responsible for resolving conflict of linguistic representations (phonological, syntactic & semantic; see January et al., 2008; Novick et al., 2005). The latter strand of research argues that BA 45 is part of a network regulating domain-general cognitive control, which is, for instance assumed to be activated during syntactic ambiguity resolution. In essence, we cannot resolve this question. However, at least in our test scenario, there is a distinct source accounting for the increased working memory load due to structural complexity in BA 45, but not for the main effect 'ambiguity'. Nevertheless, this activation might reflect domain-general control of working memory but not necessarily a functional specialization for syntax, as it has been evidenced that Broca's area is also involved in Working Memory in general (see Wager & Smith, 2003).

It is now widely accepted that theta (4-7Hz) and gamma oscillations (30-120Hz) play a vital role in memory-related processes. Typically, theta oscillations correlate with WM load and functionally connect neuronal assemblies in the frontal and parietal cortices during the maintenance of information in WM (Doppelmayr et al, 1999; Kahana et al. 1999; Klimesch et al., 1999; see Ulhaas et al, 2008 for review).

The importance of gamma oscillations for memory has for instance been demonstrated by Tallon-Baudry et al. (1992) who examined ongoing EEG modulations during a visual short-term memory task. As gamma oscillations were observed in the delay period over frontal and parietal surface areas, they suggested that gamma oscillations are important for the maintenance of information in WM.

In agreement with these assumptions, we found an increase of power in the theta frequency range for both sentence contrasts, the low-load and high-load garden-path conditions compared to their respective baseline condition. The surface effects were represented by a largely distributed network over frontal and parietal sensor areas. The low-load condition contrast included bilateral frontal areas as well as right parietal areas, and was generally stronger over right hemisphere regions. By contrast the theta effects in the high-load garden-path condition was confined to a fronto-temporo-parietal networks in the left hemisphere. The sources accounting for these effects showed some communalities for the high-load comparison vs. low-load comparison, but also some differences: Both condition contrasts localized in BA 40, however this effect engaged the right hemisphere in the low-load conditions, while the high-load conditions engaged mainly the left hemisphere, although there was also some activation in the right hemisphere in BA 40. BA 40, particular the left-lateral region, is considered part of the language network during reading, but has been shown to be bilaterally activated during word processing. In addition to this, we identified frontal brain sources that accounted for the theta synchronization effect: the low-load condition contrast localized in right-lateral BA 45, while the high-load condition contrast activated anterior cingulate areas (BA 24). The anterior cingulate is a region not only associated with error detection and conflict monitoring, but also the monitoring of effort.

In line with Posner (1995), this finding emphasizes the involvement of anterior cingulate regions in controlled processing when faced with increased cognitive demand. Posner implied that the anterior cingulate is recruited when the subject's attention is consciously directed towards a specific target, as opposed to mechanisms involved in automatic or passive processing.

It is intriguing that we only observed modulations in the gamma frequency band for the high-load garden-path comparison. This might suggest that indeed, introducing a more complex phrase that also adds an additional referent imposes greater load than the

initial adverbial phrase in the low-load condition contrast. We identified two different gamma effects: a transient increase in gamma power in low gamma (35-60Hz) and a long-lasting increase in high gamma (80-120Hz). Both of these effects were confined to frontal and temporal areas over the left hemisphere. The source accounting for the low gamma effect was the left superior frontal gyrus (BA 6), while the high gamma effect was localized in the precentral gyrus (BA 4). Importantly, the low gamma effect is in agreement with recent reports that memory effects lead to increased gamma (55-56Hz) in left BA 6 during encoding and maintenance of word lists (Meeuwissen et al, 2010). Similarly, Howard and colleagues reported that gamma band activity increased with memory load in the left precentral gyrus (BA 4) while subjects performed a Sternberg task.

What appears rather puzzling is the synchronization effect (i.e. an *increase* in power) in the alpha (8-14Hz) and the beta (14-26Hz) frequency bands for both, high-load and low-load garden-path sentences compared to their respective baseline. Findings from research investigating WM and visuospatial attention (Sauseng et al., 2007; Jensen et al., 2002; Jokisch et al., 2007) have related alpha synchronization effects to functional inhibition, in particular when capacity limits are reached. Low-load and high-load garden-path sentences engaged both bilateral frontal-midline and right temporo-parietal sensor areas. However the alpha effect was for both comparisons strongest over left-frontal regions. Likewise, the sources accounting for these effects both engaged the left superior frontal gyrus (low-load comparison: BA 8; high-load comparison: BA 10) - regions that have been implicated in WM and LTM (long-term memory) tasks (e.g. Ranganath et al, 2003). A second source for the high-load comparison was identified in the posterior cingulate gyrus (BA 31).

The sensor-level beta effect in the low-load comparison engaged large-scale networks in bilateral frontal and left temporo-parietal regions. The effect was transient for the high-load comparison over frontal areas, and more pronounced over bilateral

temporo-parietal sensor areas. The source representative for the effect in the low-load comparison was located in the left parietal lobe (BA 3), while the sources accounting for the beta effect in the high-load comparison were identified in the right frontal medial lobe (BA 10) and the left superior temporal gyrus (BA 31). Importantly, BA 10 is usually involved in strategic processes of memory retrieval and executive functions.

It has been claimed that beta synchronization facilitates coherence over large distances. For instance Schnitzler and Gross (2004, 2005) reported that communication between fronto-parieto-temporal attentional networks take place via long-range phase synchronization in the beta frequency band. In terms of language processing, the beta band has been implied to play a role in syntactic unification (Bastiaansen & Hagoort, 2006). In a more recent study that investigated word category ambiguities, Piantoni (2008) found beta frequency increases at the ambiguous word. He suggested that increased power in the higher-beta (20–22 Hz) in the time window 150–500ms post-stimulus may indicate that ambiguity processing involves competition at the ambiguous word. The alpha and beta synchronization effects we observe in our data may be either driven by the activation of competing interpretations during garden-path processing or caused by functional inhibition because WM limits are reached. Alas, at this stage we are not able to disentangle the specific contributions of 'ambiguity' as compared to 'cognitive load' towards the described frequency effects. To sum up our data suggests that increased working memory load induced by syntactic complexity leads to activation in large-scale networks in the oscillatory profile and reliably activated prefrontal regions associated with the maintenance of Working Memory and executive control.

## 6. General Discussion

Language is a highly complex cognitive skill and ultimately the cognitive trait that defines us as being human. Still, it is a task that people perform very quickly and in a highly efficient manner, even when they are faced with conflicting information. When we encounter unexpected or erroneous input, compensating adjustments are triggered on-the-fly in order to make sense of what has been said. Inevitably, language comprehension requires a mix of automatic and controlled processes (see Posner and Snyder, 1957) and, depending on the context, we engage in both to varying degrees. While automatic processes are typically rapid and require little monitoring or conscious attention, controlled processes step in whenever on-line computations require some kind of regulation: Among those situations are for instance when the brain has to select between competing representations, inhibit irrelevant information, and importantly, when a conflict signal triggers strategic adjustments to be made.

Many neuroimaging studies in Psychology have shown that the pivotal brain region that supports this ability is the prefrontal cortex (PFC; e.g., Miller & Cohen, 2001). The PFC is also crucial in the control of other forms of higher-order cognition, for instance the maintenance of working memory. As executive control processes and the resulting activation in structures of the prefrontal cortex seem to generalize across various perceptual tasks, people often refer to them as domain-general.

In recent years, there have been heated discussions about whether language relies on specialized neural systems or whether it is supported by flexible domain-general systems that enable us, for instance, to solve arithmetic problems or to manipulate information held in working memory. Already fifty years ago, research based on philosophical and linguistic grounds has tried to tackle the question whether there is a relationship between language processing and domain-general mechanisms (Fodor, 1988; Miller & Chomsky, 1963), while more recently, neuroimaging techniques provided information how language processing relates to domain-general resources (Grodzinsky &

Friederici, 2006; Kaan & Swaab, 2002; Federenko et al, 2011). Lately, there has been a shift from the idea that cognitive brain functions depend on independent processors for specific complex functions towards the belief that higher cognition critically relies on the large-scale organization of the brain. One of the most prominent frequency bands implied in the coordination of local as well as long-range neural networks during the recruitment of controlled processes is the theta frequency band (4-7Hz). Moreover, theta power has also been shown to be sensitive to conflict monitoring and conflict processing, and typically increases in amplitude with increasing load during maintenance in WM tasks.

In this thesis I used structures that are amongst the most well-studied in psycholinguistic research in order to investigate how the brain copes with linguistic conflicts.

In particular, we were interested under which circumstances conflict-induced control is reflected in activation of large-scale networks with underlying sources in the prefrontal cortex and under which circumstances they are processed in a more automatized fashion. Specifically, we were interested in the underlying oscillatory dynamics during linguistic conflict resolution, as evidence for this is still rare in the language domain. ERPs have limited value for exploring the processes involved in large-scale synchronization and, crucially, different sources can account for the same ERP surface component. Clearly, the one-to-one mapping between – broadly speaking - the N400 as a marker of semantic conflicts and the P600 as an index for syntactic conflicts has failed. However, we hoped to gain some insights about these components by complementing the time-amplitude analysis with the analysis in the time-frequency domain and source domain.

Our results suggest that there is indeed a relationship between the language system and the executive system during linguistic conflict processing, and it seems to hold across presentation modalities (auditory and visual): This appears to be the case when the parser has to select between competing representations and inhibit an initially

preferred interpretation towards a less preferred one as illustrated during the processing of temporarily ambiguous reduced-relative clauses (Experiment 1), during the processing of agreement mismatches in sentence contexts that are uncertain with respect to future input as observed in the anaphora experiment (Experiment 2), and whenever the brain has to deal with large amounts of WM load and capacity limits are reached (MEG, Experiment 4). All of these experiments showed activation in prefrontal, anterior cingulate, as well as parietal regions in the sensor-level analysis of the frequency profile. This is likely to reflect the interplay between executive functions and domain-specific storage, particularly with respect to lexical-semantic retrieval.

Importantly, the local maximum of the sources accounting for these effects localized in PFC regions that are classically associated with controlled processing. The prominent oscillatory rhythm that we observed in these experiments was the theta rhythm, although the theta activity in the garden-path experiment (Experiment 1) was preceded by a transient decrease of beta power (16-26Hz) with maximum acticity in the ACC. This effect is most likely caused by prediction error due to disconfirmed expectations at the earliest point of disambiguation (i.e. when it is clear that the initial interpretation is wrong; see Arnal & Giraud, 2012). Also, in the MEG experiment (Experiment 4) where we investigated the effect of cognitive load induced by sentences with varying degrees of syntactically complexity, we found activation in multiple frequency bands. I will get back to these results later in this section. Nevertheless, the experiments listed above reliably exhibit power changes in areas that are often associated with flexible top-down control (dorsolateral prefrontal cortex: BA 9, BA 46; anterior cingulate cortex: BA 32, BA 24; superior frontal cortex / premotor cortex: BA 6, BA 8).

Interestingly, our data from Experiment 3 (conflicts induced by gender-agreement mismatches in cataphora sentences) provides evidence for *modularity* or automaticity during linguistic conflict resolution: Both noun types (lexical / stereotypical) elicited power changes in posterior brain areas that are typically associated with specialized

linguistic processors (BA 21, BA 40). This was reflected in localized power changes in the alpha band (8-12Hz) for the lexical nouns (herself -> king), while the gender-mismatch for the stereotypical nouns (herself -> surgeon) led to a power increase in the theta frequency band (4-7Hz). Contrary to anaphora sentences, the cataphoric reflexive precedes the co-referring noun ahead of time and unambiguously assigns a certain gender to the referent. The decrease in alpha for the lexical noun mismatch is likely to reflect increased attentional processes caused by the processing of conflicting and, more importantly, *unresolvable* information. By contrast, the short-lived theta burst in the stereotypical conditions points to a rather unconscious manner of conflict resolution. More precisely, it is likely that participants were not even able to report the encountered conflict (see Dehaene et al., 1998), but performed context updating rather oblivious to the gender mismatch.

I propose that context-based forward predictions strongly influence whether linguistic conflict resolution occurs in a more automatized manner or whether assistance 'from outside' (i.e. from domain-general networks) becomes necessary: If strong contextual cues are given, the language processor appears to rely on fast and hard-wired specialized processors, because the activation of controlled processes as for instance monitoring (which typically registers as cost) was initially not deemed necessary. Likewise, with increased uncertainty it is reasonable that the language system recruits flexible systems involved in top-down executive functions. Plainly speaking, contextual information encourages to take the line of the least resistance, which in turn promotes relatively efficient information processing. The speed with which we observed the oscillatory effects in the cataphora experiment strengthens this idea, as it is unlikely to find effects as early as we did without prior prediction.

Another intriguing observation is that in all experiments that elicited activation of large and rather distributed neuronal networks throughout the brain, the non-parametric randomisation test reliably detected multiple ERP / ERF components that carried on over

a long latency range. The garden-path experiment (Experiment 1) and the lexical condition contrast in the anaphora experiment (Experiment 2) revealed a biphasic pattern of N400-P600, though in the latter case the P600 effect co-occurred with a late left-anterior negativity. Likewise the stereotypical condition contrast in the anaphora experiment elicited a P600 component that coexisted with a left anterior negativity effect. Finally, the MEG experiment revealed that high-load as well as low-load condition contrasts resulted in early anterior negativities that were followed by temporo-parietal negativity effects and late anterior negativity effects. Contrary to that, in the cataphora experiment where conflict processing elicited activation in posterior localized networks, we found single early and short-lived ERP components (LAN / P300). Given the fact that some have argued that oscillations superimpose ERP components (cf. Röhm, 2004), I propose the tentative idea that multiple ERP components may indicate the activation of large-scale networks and therein the activation of executive functions when faced with linguistic conflict.

Let us return to Experiment 4, the MEG experiment in which I manipulated load by embedding syntactic garden-path sentences into sentence contexts with varying syntactic complexity. In this experiment I found that increased load results in long-range network activation in various frequency bands throughout the cortex with source activation of PFC regions. Prominent frequency bands implied in tasks employing WM manipulations are the gamma and theta band. At the same time, activity in the gamma frequency has been shown to be modulated by theta rhythms during cognitive and perceptual processing (e.g. Schack et al., 2002; 2008). As mentioned above I observed increases in power in the theta frequency band at the earliest point of disambiguation for the high-load condition contrast as well as the low-load condition contrast. However, I observed increases of gamma power *only* for the high-load condition contrast, suggesting that these conditions indeed imposed greater cognitive load. The gamma activity was represented by two separate effects - a transient low-gamma increase and a long-lasting

high-gamma effect. Whether these effects designate distinct processes or whether they co-exist, remains unclear. Studies investigating the human visual cortex however have evidenced that slow and fast gamma oscillations occur together, but are involved in different aspects of visual information processing (Tallon-Baudry et al., 2005; Vidal et al., 2006; Wyart & Tallon- Baudry, 2008). Similarly, the inhibition effects observed in the alpha and beta frequency still demand further investigation. At this point, I am not able to separate the contributions of the ambiguity effect due to garden-path processing from the contributions of the load effect due to syntactic complexity in the time-frequency domain. Typically, these effects are thought to interact strongly, and even simple garden-path sentences have proven to impose increased load on the Working Memory system. However, the activation in BA 10 in the alpha frequency (low-load condition contrast) and the beta band (high-load condition contrast), might point to the organization of WM, as this area is assumed to be involved in strategic processes of memory retrieval and executive functions.

The amplitude-time analysis revealed that only the early anterior negativity component was significantly different (i.e. more pronounced) for the high-load garden-path condition compared to the low load garden-path condition. The subsequent beamforming technique localized the source accounting for the simple effect 'load' in BA 45 (Broca's area).

In the amplitude-time domain, I investigated whether this effect was caused by the overall garden-path effect or whether it is attributable to cognitive load due to syntactic complexity by collapsing over the respective conditions. In line with the source accounting for the simple effect 'load', the main effect 'load' also localized in BA 45. By contrast, the main effect 'ambiguity' localized in the right inferior frontal gyrus (BA 47) and the left middle frontal gyrus (BA 6). These brain regions generally represent areas activated during the recruitment of domain-general control. Historically, BA 45 has been strongly tied to syntactic processing, particularly during the processing of syntactically

complex sentences. This result may suggest a functional role of BA 45 in syntactic processing, were it not for the fact that this area is also sensitive to WM manipulations outside the language domain. In view of this I would like to suggest that BA 45 is likely to manipulate and coordinate information held in WM across various domain and is not limited to verbal manipulations.

Similarly, across two experiments that showed links between the language system and domain-general executive functions (Experiment 1, Experiment 4) I found evidence for motor (BA 4) and pre-motor activation (BA 6, BA 8) during linguistic conflict resolution. Activation in BA 8 typically increases with increased uncertainty, which is quite sensible in the context of syntactic garden-path sentences where uncertainty originates from ambiguous input. Although activation in these areas is usually found in neuroimaging studies of spoken language processing (see e.g. Szenkovits et al. 2012), in my experiments this effect generalizes across presentation modalities. Experiment 1 used spoken garden-path sentences, while Experiment 4 used visual presentation. Importantly however, I used the exact same sentence type, i.e. the reduced-relative clause in both experiments, with the additional factor of syntactic complexity in Experiment 4. Therefore, the activation of these brain regions may be particularly sensitive to this sentence type.

With respect to neurocognitive models of sentence processing, the data I presented seems to be more in agreement (i.e. both for ERPs and TFRs) with Hagoort's function-oriented MUC model (2003, 2005) than with Friederici's serial model that is based on the temporal order of language-related ERP components (2002). The MUC model consist of three components: a) *Memory*, which deals with the retrieval of lexical-semantic information or more precisely the retrieval of syntactic frames, b) *Unification*, which combines these frames together, and c) *Control,* which becomes important whenever executive planning and attentional control is necessary. These functionally separate components interact to combine single word information together into a

coherent representation. Within this framework, the left temporal cortex represents the 'hub' for the *Memory* component and the retrieval of lexical-semantic information has been particularly related to changes in theta frequency power. The brain region that has been linked to *Unification* in this framework is the left inferior frontal gyrus (LIFG, BA 44/45/47). By contrast, the *Control* component is thought to be supported by a network of areas involving the anterior cingulate cortex (BA 24/32) and the dorsolateral prefrontal cortex (BA 46/9). In agreement with these claims, I reliably and repeatedly found activation of these networks during linguistic conflict resolution. However, the MUC thoroughly endorses the left hemisphere as 'core processor', whereas my data regularly showed right hemisphere activation. I would like to put forward that right hemisphere regions substantially contribute to the *Control* component and a less rigorous localization of this system might be more adequate.

It is also possible to relate my results to different theories of consciousness such as the *attentional network theory* (Posner and Petersen, 1990) and the *conscious neuronal workspace* (Dehaene & Changeux, 2000; Dehaene, Kerszberg, & Changeux, 1998; Dehaene & Naccache, 2001; Dehaene, Sergent, & Changeux, 2003). The attentional network theory proposes that human attentional processes consist of three specialized networks that are conceptualized as a system of anatomical brain regions (Fan et al., 2005). Functions of these networks are alerting to acquire and maintain alertness, orienting to turn attention toward a sensory signal, and executive control for conflict monitoring and conflict resolution. The alerting network involves activation of anterior and posterior cortical sites, the orienting network activates frontal and parietal sites, and the executive control network increases activation of the anterior cingulate cortex (ACC) along with lateral prefrontal cortex.

Much the same, the neuronal workspace theory stresses the importance of distributed neurons with long-distance connections that are particularly clustered in

prefrontal, anterior cingulate, and parietal regions. These neurons enable the brain to connect multiple specialized modules and stimulate spontaneous broadcasting of information to multiple neural areas. Importantly, these areas are not activated during automatized tasks, but appear active suddenly when an automatized tasks triggers conscious control.

Contrary to that, with automatisation, activation typically decreases in dlPFC (dorsolateral prefrontal cortex) and ACC (anterior cingulate cortex). Therefore, automatic processing results in activation in specialized processors throughout the cortex, but does not require the coordination of global workspace neurons through large-scale networks. The distinction between domain-specific processors that behave in a highly automatic and fast fashion (as observed in the cataphora experiment (Exp. 3)) and a separate central control system that conveys information across the domain-specific modules (Exp. 1, 2, and 4) fits well with our data.

**Limitations, possible confounds, and future work**

A major challenge that remains and that I cannot address at this point is how the dynamic flow of information between the language system and domain-general executive system (and vice versa) takes place. The results I reported here represent a more functional segregation rather than an approach to establish how information is transmitted and integrated across brain networks during linguistic conflict resolution. A way to approach this is functional connectivity analysis, which is based on the notion that functionally interacting regions show correlated patterns of activity. In future work, I will try to overcome this limitation by applying functional connectivity measures to determine which circumstances lead to recruitment of some networks over others and how networks interact when trying to overcome linguistic conflicts. Another matter that I have not investigated yet is the contribution of individual differences towards the effects

I reported here. There have been various reports that individuals' performance varies to quite some extent in tasks involving syntactic processing (e.g., King and Just, 1991; MacDonald et al., 1992; Novick et al., 2005), hence it would be beneficial to investigate how this affects the results of my experiments.

### *Possible confounds*

Conversely, a number of psycholinguistic studies have shown that words semantically related to motor actions such as for instance "kick" or "pick" result in differential activations of motor areas during comprehension (see e.g., Pulvermüller, 1999). Specifically, words linked to actions are assumed to activate the pre-motor and motor cortex in a somatotopic manner (Hauk, Johnsrude, & Pulvermüller, 2004; Pulvermüller et al., 2001). It has been argued that motor activation even reflects fine-grained referential meaning of action-related words (Pulvermüller, Shtyrov, Hauck, 2009). For instance, leg-related words such as "kick" reliably result in activation of dorsal areas that are activated during leg movements while words such as "pick" elicit activation of lateral or inferior frontal motor areas. In view of this it stands to argue that the motor and pre-motor area activation observed in the "garden-path" experiments Experiment 1 and Experiment 4 may be due to the actual verbs used in the experimental items. To clarify this issue, it is necessary to isolate experimental items that contain verbs referring to actions from those that are not action-related and to perform a by-item analysis. Also, the onset of the critical word "by" (the earliest point of disambiguation) and to which the analysis was time-locked to, differs between the garden-path condition and its unambiguous control condition (the full relative clause, which contains two more words before the "by" is encountered). This difference may account for the differences I observed between the conditions. Nevertheless, there is always a certain trade-off, as adding two more words to the garden-path conditions may similarly induce unwanted effects.

**Final Conclusion**

There is no doubt that language is special, and our brain contains sophisticated linguistic resources, which are implemented in functionally specialized neural circuits. The results I reported in this thesis support the notion that there is indeed a connection between the language system and general executive functions during linguistic conflict processing, but that there are also situations where specialized 'modules' perform conflict resolution in a highly automatized fashion. Moreover, the results show that when contextual information sufficiently cues future input, conflicting information is more likely to be resolved within the language system itself. However, as soon as uncertainty comes into play or capacity limits are reached, the brain appears to rely on extremely flexible mechanisms in prefrontal cortex regions. However, the mechanisms underlying linguistic conflict processing still remain unclear and more research is needed to clarify this question. I would like to honour my roots as a computational linguist and conclude my final remarks by citing a man that is not only known for his controversial political opinions, but also for being the "father of modern linguists". In the end, it always comes down to what Noam Chomsky once said: "How is it we have so much information, but know so little?"

# References

Adrian, E. D., & Matthews, H. C. (1934). The Berger Rhythm: potential changes from the occipital lobes in man, *57*(4), 24–385.

Allefeld, C., Frisch, C. A. S., & Schlesewsky, M. (2005). Detection of early cognitive processing by event-related phase synchronization analysis. *NeuroReport*.

Allen, M., Badecker, W., & Osterhout, L. (2003). Morphological analysis in sentence processing: An ERP study. *Language and Cognitive Processes*, *18*(4), 405–430.

Almor, A. (1999). Noun-phrase anaphora and focus: The informational load hypothesis. *Psychological Review*, *106*(4), 748–765. doi:10.1037//0033-295X.106.4.748

Altmann, G. T., & Kamide, Y. (1999). Incremental interpretation at verbs: restricting the domain of subsequent reference. *Cognition*, *73*(3), 247–64.

Angrilli, A., Penolazzi, B., Vespignani, F., De Vincenzi, M., Job, R., Ciccarelli, L., Palomba, D., et al. (2002). Cortical brain responses to semantic incongruity and syntactic violation in Italian language: an event-related potential study. *Neuroscience letters*, *322*(1), 5–8.

Ariel, M. (1990). *Accessing Noun-Phrase Antecedents*. London & New York: Routledge.

Ariel, M. (1991). The function of accessibility in a theory of grammar. *Journal of Pragmatics*, *16*(5), 443–463. doi:10.1016/0378-2166(91)90136-L

Arnal, L. H., & Giraud, A.-L. (2012). Cortical oscillations and sensory predictions. *Trends in cognitive sciences*, *16*(7), 390–8.

Arnal, L. H., Wyart, V., & Giraud, A.-L. (2011). Transitions in neural oscillations reflect prediction errors generated in audiovisual speech. *Nature neuroscience*, *14*(6), 797–801.

Baddeley, a. D., Hitch, G. J., & Allen, R. J. (2009). Working memory and binding in sentence recall. *Journal of Memory and Language*, *61*(3), 438–456.

Baddeley, A D, & Hitch, G. J. (2000). Development of working memory: should the Pascual-Leone and the Baddeley and Hitch models be merged? *Journal of Experimental Child Psychology*, *77*(2), 128–137.

Baddeley, A.D. (1986). *Working Memory. The psychology of learning and motivation: Advances in research and theory*. Oxford: Oxford University Press.

Baddeley, Alan D, & Logie, R. H. (1999). Working memory: The multiple-component model. In A. Miyake & P. Shah (Eds.), *Models of working memory Mechanisms of active maintenance and executive control* (pp. 28–61). Cambridge University Press.

Bahlmann, J., Schubotz, R. I., & Friederici, A. D. (2008). Hierarchical artificial grammar processing engages Broca's area. *NeuroImage*, *42*(2), 525–534. Retrieved from

Banaji, M. R., & Hardin, C. D. (1995). AUTOMATIC STEREOTYPING. *PSYCHOLOGICAL SCIENCE*, *7*(3), 136–141.

Bar, M. (2007). The proactive brain: using analogies and associations to generate predictions. *Trends in Cognitive Sciences*, *11*(7).

Barber, H., & Carreiras, M. (2005). Grammatical gender and number agreement in Spanish: an ERP comparison. *Journal of cognitive neuroscience*, *17*(1), 137–53.

Bas, E., & Schurmann, M. (2001). Gamma , alpha , delta , and theta oscillations govern cognitive processes. *International Journal of Psychophysiology*, *39*, 241–248.

Basar-Eroglu, C., Brand, A., Hildebrandt, H., Karolina Kedzior, K., Mathes, B., & Schmiedt, C. (2007). Working memory related gamma oscillations in schizophrenia patients. *International journal of psychophysiology : official journal of the International Organization of Psychophysiology*, *64*(1), 39–45.

Bastiaansen, M. C., & Brunia, C. H. (2001). Anticipatory attention: an event-related desynchronization approach. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology*, *43*(1), 91–107.

Bastiaansen, M. C., & Knösche, T. R. (2000). Tangential derivative mapping of axial MEG applied to event-related desynchronization research. *Clinical neurophysiology: official journal of the International Federation of Clinical Neurophysiology*, *111*(7), 1300–5.

Bastiaansen, M. C. M., Berkum, J. J. A. V., & Hagoort, P. (2002). Syntactic Processing Modulates the  Rhythm of the Human EEG. *NeuroImage*, *1492*, 1479 –1492.

Bastiaansen, M. C. M., van Berkum, J. J. a, & Hagoort, P. (2002). Event-related theta power increases in the human EEG during online sentence processing. *Neuroscience letters*, *323*(1), 13–6.

Bastiaansen, M. C. M., van der Linden, M., Ter Keurs, M., Dijkstra, T., & Hagoort, P. (2005). Theta responses are involved in lexical-semantic retrieval during language processing. *Journal of cognitive neuroscience*, *17*(3), 530–41.

Bastiaansen, M., & Hagoort, P. (2003). Event-induced theta responses as a window on the dynamics of memory. *Cortex*, *39*(4-5), 967–92. Retrieved from

Bastiaansen, M., & Hagoort, P. (2006). Oscillatory neuronal dynamics during language comprehension. *Brain*, *159*, 179–196.

Bastiaansen, M., Magyari, L., & Hagoort, P. (2010). Syntactic unification operations are reflected in oscillatory dynamics during on-line sentence comprehension. *Journal of cognitive neuroscience*, *22*(7), 1333–47.

Bastiaansen, M., Mazaheri, A., & Jensen, O. (n.d.). Beyond ERP's: oscillatory neuronal dynamics.

Başar, E., & Schürmann, M. (1997). Functional correlates of alphas panel discussion of the conference "Alpha Processes in the Brain". *International journal of psychophysiology : official journal of the International Organization of Psychophysiology*, *26*(1-3), 455–74.

Başar, E., Schürmann, M., Başar-Eroglu, C., & Demiralp, T. (2001). Selectively distributed gamma band system of the brain. *International journal of psychophysiology : official journal of the International Organization of Psychophysiology*, *39*(2-3), 129–35.

Başar-Eroglu, C., Strüber, D., Schürmann, M., Stadler, M., & Başar, E. (1996). Gamma-band responses in the brain: a short review of psychophysiological correlates and functional significance. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology*, *24*(1-2), 101–12.

Beim Graben, P., Gerth, S., & Vasishth, S. (2008). Towards dynamical system models of language-related brain potentials. *Cognitive neurodynamics*, *2*(3), 229–55.

Bendixen, A., SanMiguel, I., & Schröger, E. (2012). Early electrophysiological indicators for predictive processing in audition: a review. *International journal of psychophysiology : official journal of the International Organization of Psychophysiology*, *83*(2), 120–31.

Berger, H. (1929). Über das Elektroenkephalogram des Menschen. *Arch. f. Psychiat.*, *87*, 527–570.

Besl, P. J., & McKay, N. D. (1992). A Method for Registration of 3-D Shapes. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *14*(2).

Bever, T. G. (1970). The cognitive basis for linguistic structures. In J. R. Hayes (Ed.), *The cognitive basis for linguistic structures* (pp. 279–362). New York: Wiley.

Blumenfeld, R. S., & Ranganath, C. (2006). Dorsolateral prefrontal cortex promotes long-term memory formation through its role in working memory organization. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *26*(3), 916–25.

Bor, D., Cumming, N., Scott, C. E. L., & Owen, A. M. (2004). Prefrontal cortical involvement in verbal encoding strategies. *The European journal of neuroscience*, *19*(12), 3365–70. d

Bor, D., & Owen, A. M. (2007). A common prefrontal-parietal network for mnemonic and mathematical recoding strategies within working memory. *Cerebral cortex (New York, N.Y. : 1991)*, *17*(4), 778–86.

Bornkessel, I. (2002). *The Argument Dependency Model : A Neurocognitive Approach to Incremental Interpretation.* (28th ed., Vol. 2002). MPI Series in Cognitive Neuroscience.

Bornkessel, I., Mcelree, B., Schlesewsky, M., & Friederici, A. D. (2004). Memory and Language Multi-dimensional contributions to garden path strength : Dissociating phrase structure from case marking q. *Journal of Memory and Language*, *51*, 495–522.

Bornkessel, I., & Schlesewsky, M. (2006). The extended argument dependency model: a neurocognitive approach to sentence comprehension across languages. *Psychological review*, *113*(4), 787–821.

Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2009). Minimality as vacuous distinctness: Evidence from cross-linguistic sentence comprehension. *Lingua*, *119*(10), 1541–1559. doi:10.1016/j.lingua.2008.03.005

Bornkessel-schlesewsky, I., & Schlesewsky, M. (2008). An alternative perspective on " semantic P600" effects in language comprehension. *Brain Research Reviews*, *59*(1), 55–73.

Botvinick, M. M., Carter, C. S., Braver, T. S., Barch, D. M., & Cohen, J. D. (2001). Conflict Monitoring and Cognitive Control. *Psychological Review*, *108*(3), 624–652.

Brown, C. M., & Hagoort, P. (1993). The processing nature of the N400: evidence from masked priming. *Journal of Cognitive Neuroscience*, *5*, 34–44.

Bubic, A., von Cramon, D. Y., & Schubotz, R. I. (2010). Prediction, cognition and the brain. *Frontiers in human neuroscience*, *4*(March), 25.

Buzsáki, G., & Draguhn, A. (2004). Neuronal oscillations in cortical networks. *Science (New York, N.Y.)*, *304*(5679), 1926–9.

Caplan, D., & Waters, G. S. (1999). Verbal working memory and sentence comprehension. *The Behavioral and brain sciences*, *22*(1), 77–94; discussion 95–126.

Carreiras, M., Garnham, A., Oakhill, J., & Cain, K. (1996). The use of stereotypical gender information in constructing a mental model: evidence from English and Spanish. *Quarterly Journal of Experimental Psychology*, *49*(3), 639–663.

Carruthers, P. (n.d.). Language in Cognition.

Carruthers, P. (1983). Distinctively human thinking: modular precursors and components, 1–29.

Carruthers, P. (2008). On Fodor-Fixation, Flexibility, and Human Uniqueness: A Reply to Cowie, Machery, and Wilson. *Mind & Language, 23*(3), 293–303.

Carter, C. S. (1998). Anterior Cingulate Cortex, Error Detection, and the Online Monitoring of Performance. *Science*, *280*(5364), 747–749.

Changeux, J. P., & Dehaene, S. (2000). Hierarchical neuronal modeling of cognitive functions: from synaptic transmission to the Tower of London. *Comptes rendus de lAcademie des sciences Serie III Sciences de la vie*, *35*(2-3), 241–247.

Chomsky, N., & Miller, G. A. (1963). ntroduction to the formal analysis of natural languages. In R. D. Luce, R. R. Bush, & E. Galanter (Eds.), *Handbook of mathematical psychology* (pp. 169–321). New York: Wiley.

Chomsky, Noam. (1965). *ASPECTS OF THE THEORY OF SYNTAX*. Cambridge, Massachusetts: The MIT Press.

Chomsky, Noam. (1981). *Lectures on government and binding the Pisa lectures Studies in generative grammar*. *Book* (p. 371). Foris publications.

Choudhary, K. K., Schlesewsky, M., Roehm, D., & Bornkessel-Schlesewsky, I. (2009). The N400 as a correlate of interpretively relevant linguistic rules: evidence from Hindi. *Neuropsychologia*, *47*(13), 3012–22.

Christensen, K. (2008). Interfaces, syntactic movement, and neural activation: A new perspective on the implementation of language in the brain. *Journal of Neurolinguistics*, *21*(2), 73–103.

Christensen, K. R. (2010). Syntactic reconstruction and reanalysis, semantic dead ends, and prefrontal cortex. *Brain and cognition*, *73*(1), 41–50.

Clifton, C., Frazier, L., & Rayner, K. (n.d.). Perspectives on sentence processing. In K. Rayner (Ed.), *1994* (p. 483). L. Erlbaum Associates .

Clifton, C., Traxler, M. J., Mohamed, M. T., Williams, R. S., Morris, R. K., & Rayner, K. (2003). The use of thematic role information in parsing: Syntactic processing autonomy revisited. *Journal of Memory and Language*, *49*(3), 317–334.

Cohen, M. X., & Cavanagh, J. F. (2011). Single-Trial Regression Elucidates the Role of Prefrontal Theta Oscillations in Response Conflict. *Frontiers in Psychology*, *2*(February), 1–12.

Coulson, S., King, J. W., & Kutas, M. (1998). Expect the Unexpected : Event-related Brain Response to Morphosyntactic Violations. *Cognitive Science*, *13*(1), 21–58.

Crain, S., & Fodor, J. D. (1985). How can grammars help parsers? In D. R. Dowty, L. Karttunen, & A. M. Zwicky (Eds.), *Natural Language Parsing: Psychological, Computational, and Theoretical Perspectives* (pp. 94–128). Cambridge: Cambridge University Press.

Damasio, H., Grabowski, T. J., Tranel, D., Hichwa, R. D., & Damasio, A. R. (1996). A neural basis for lexical retrieval. *Nature*, *380*, 499–505.

Daneman, M., & Carpenter, P. (1980). Individual differences in working memory and reading. *Journal Of Verbal Learning And Verbal Behavior*, *19*(4), 450–466.

DeLong, K. a, Urbach, T. P., Groppe, D. M., & Kutas, M. (2011). Overlapping dual ERP responses to low cloze probability sentence continuations. *Psychophysiology*, *48*(9), 1203–7.

DeLong, K. a, Urbach, T. P., & Kutas, M. (2005). Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. *Nature neuroscience*, *8*(8), 1117–21.

Dehaene, S, Kerszberg, M., & Changeux, J. P. (1998). A neuronal model of a global workspace in effortful cognitive tasks. *Proceedings of the National Academy of Sciences of the United States of America*, *95*(24), 14529–34.

Dehaene, S, & Naccache, L. (2001). Towards a cognitive neuroscience of consciousness: basic evidence and a workspace framework. *Cognition*, *79*(1-2), 1–37.

Dehaene, S., Posner, M. I., & Tucker, D. M. (1994). Localization of a neural system for error detection and compensation. *Psychological Sciences*, *5*(5), 303–305.

Dehaene, Stanislas, Artiges, E., Naccache, L., Martelli, C., Viard, A., Schu, F., Recasens, C., et al. (2003). Conscious and subliminal conflicts in normal subjects and patients with schizophrenia: The role of the anterior cingulate. *PNAS*.

Dehaene, Stanislas, Cohen, L., Sigman, M., & Vinckier, F. (2005). The neural code for written words: a proposal. *Trends in cognitive sciences*, *9*(7), 335–41.

Dehaene, Stanislas, Sergent, C., & Changeux, J.-P. (2003). A neuronal network model linking subjective reports and objective physiological data during conscious perception. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(14), 8520–5.

Dikker, S., & Pylkkanen, L. (2011). Before the N400: effects of lexical-semantic violations in visual cortex. *Brain and language*, *118*(1-2), 23–8.

Dikker, S., Rabagliati, H., & Pylkkänen, L. (2009). Sensitivity to syntax in visual cortex. *New York*, *110*, 293–321.

Duffy, S. A., & Keir, J. A. (2004). Violating stereotypes: eye movements and comprehension processes when text conflicts with world knowledge. *Memory cognition*, *32*(4), 551–559.

Duncun-Johnson, C. C., & Donchin, E. (1977). On Quantifying Surprise: The Variation of Event-Related Potentials With Subjective Probability. *Psychophysiology*, *14*(5), 456–467.

D'Esposito, M., & Postle, B. R. (1999). The dependence of span and delayed-response performance on prefrontal cortex. *Neuropsychologia*, *37*(11), 1303–15.

Engel, A. K., & Fries, P. (2010). Beta-band oscillations--signalling the status quo? *Current opinion in neurobiology*, *20*(2), 156–65.

Engel, A. K., Fries, P., & Singer, W. (2001). Dynamic predictions: oscillations and synchrony in top-down processing. *Nature reviews. Neuroscience*, *2*(10), 704–16.

Escudero, J., Hornero, R., Abásolo, D., Fernández, A., & López-Coronado, M. (2007). Artifact removal in magnetoencephalogram background activity with independent component analysis. *IEEE Transactions on Biomedical Engineering*, *54*(11), 5282–5285.

Falkenstein, M., Hoormann, J., Christ, S., & Hohnsbein, J. (2000). ERP components on reaction errors and their functional significance: a tutorial. *Biological psychology*, *51*(2-3), 87–107.

Fan, J. (2003). Cognitive and Brain Consequences of Conflict. *NeuroImage*, *18*(1), 42–57.

Fan, Jin, Byrne, J., Worden, M. S., Guise, K. G., McCandliss, B. D., Fossella, J., & Posner, M. I. (2007). The relation of brain oscillations to attentional networks. *The Journal of Neuroscience*, *27*(23), 6197–206.

Federmeier, K. D. (2007). Thinking ahead: the role and roots of prediction in language comprehension. *Psychophysiology*, *44*(4), 491–505.

Felser, C., Clahsen, H., & Münte, T. F. (2003). Storage and integration in the processing of filler-gap dependencies: An ERP study of topicalization and wh-movement in German. *Brain and Language*, *87*(3), 345–354.

Fernandez-Duque, D. (2009). Cognitive and neural underpinnings of syntactic complexity. In T. Givon & M. Shibatani (Eds.), *The genesis of syntactic complexity* (pp. 433–460). J. Benjamin Publisher.

Ferreira, F., & Clifton, C. (1986). The independence of syntactic processing. *Journal of Memory and Language*, *25*(3), 348–368.

Fiebach, C J, Schlesewsky, M., & Friederici, a D. (2001). Syntactic working memory and the establishment of filler-gap dependencies: insights from ERPs and fMRI. *Journal of psycholinguistic research*, *30*(3), 321–38.

Fiebach, Christian J., Schlesewsky, M., & Friederici, A. D. (2002). Separating syntactic memory costs and syntactic integration costs during parsing: the processing of German WH-questions. *Journal of Memory and Language*, *47*(2), 250–272.

Fodor, J. A. (1983). The modularity of mind. *Philosophical Review*.

Fodor, J., Bever, A., & Garrett, T. G. (1974). *The Psychology of Language: An Introduction to Psycholinguistics and Generative Grammar*. Mcgraw-Hill.

Fodor, J. D., & Inoue, A. (1994). The diagnosis and cure of garden paths. *Journal of Psycholinguistic Research*, *23*(5), 407–434.

Fodor, J. D., & Inoue, A. (2000). Garden Path Repair: Diagnosis and Triage. *Language and Speech*, *43*(3), 261–271.

Fodor, Janet Dean, & Inoue, A. (1994). The Diagnosis and Cure of Garden Paths. *Journal of Psycholinguistic Research*, *23*(5), 407–434.

Fodor, Jerry A. (2000). *The Mind Doesn't Work That Way: The Scope and Limits of Computational Psychology*. *Representation and mind* (Vol. 10, p. 126). MIT Press.

Frazier, L. (1987). Sentence processing: a tutorial review. *Attention and performance XII: The Psychology of Reading* (pp. 559–586). Erlbaum.

Frazier, Lyn, & Fodor, J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition*, *6*(4), 291–325.

Frazier, Lyn, & Rayner, K. (1982). Making and correcting errors during sentence comprehension: Eye movements in the analysis of structurally ambiguous sentences. *Cognitive Psychology*, *14*(2), 178–210.

Frenzel, S., Schlesewsky, M., & Bornkessel-Schlesewsky, I. (2011). Conflicts in language processing: a new perspective on the N400-P600 distinction. *Neuropsychologia*, *49*(3), 574–9.

Friederici, A D, Pfeifer, E., & Hahne, A. (1993). Event-related brain potentials during natural speech processing: Effects of semantic, morphological and syntactic violations. *Cognitive Brain Research*, *1*, 183–192.

Friederici, A. D. (1995). The time course of syntactic activation during language processing: A model based on neuropsychological and neurophysiological data. *Brain and Language*, *51*, 259–281.

Friederici, A., Hahne, A., & Mecklinger, A. (1996). Temporal structure of syntactic parsing: Early and late event-related brain potential effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(5), 1219–1248.

Friederici, Angela D. (2002). Towards a neural basis of auditory sentence processing. *Trends Cogn. Sci*, *6*(2), 78–84.

Friederici, Angela D. (2009). Pathways to language: fiber tracts in the human brain. *Trends in cognitive sciences*, *13*(4), 175–81.

Friederici, Angela D. (2011). The brain basis of language processing: from structure to function. *Physiological reviews*, *91*(4), 1357–92. 1

Friederici, Angela D, & Frisch, S. (2000). Verb Argument Structure Processing: The Role of Verb-Specific and Argument-Specific Information. *Journal of Memory and Language*, *43*(3), 476–507.

Friederici, Angela D. (1995). The Time Course of Syntactic Activation during Language Processing: A Model Based on Neuropsychological and Neurophysiological Data. *Brain and Language*, *50*, 259–281.

Friedman-Hill, S., Maldonado, P. E., & Gray, C. M. (2000). Dynamics of striate cortical activity in the alert macaque: I. Incidence and stimulus-dependence of gamma-band neuronal oscillations. *Cerebral cortex (New York, N.Y. : 1991)*, *10*(11), 1105–16.

Fries, P, Reynolds, J. H., Rorie, a E., & Desimone, R. (2001). Modulation of oscillatory neuronal synchronization by selective visual attention. *Science (New York, N.Y.)*, *291*(5508), 1560–3.

Fries, Pascal. (2005). A mechanism for cognitive dynamics: neuronal communication through neuronal coherence. *Trends in cognitive sciences*, *9*(10), 474–80.

Frye, R. E., Rezaie, R., & Papanicolaou, A. C. (2009). Functional Neuroimaging of Language Using Magnetoencephalography. *Physics of life reviews*, *6*(1), 1–10.

Garnham, A. (2001). Mental models and the interpretation of anaphora. *Essays in Cognitive Psychology*. Psychology Press.

Garrod, S. C., & Terras, M. (2000). The contribution of lexical and situational knowledge to resolving discourse roles: Bonding and resolution. *Journal of Memory and Language*, *42*(4), 526–544. /

Gaskell, G. M. (Ed.). (2007). *Oxford Handbook of Psycholinguistics* (p. 600). Oxford University Press.

Gevins, a, Smith, M. E., McEvoy, L., & Yu, D. (1997). High-resolution EEG mapping of cortical activation related to working memory: effects of task difficulty, type of processing, and practice. *Cerebral cortex (New York, N.Y.: 1991)*, *7*(4), 374–85.

Gibson, E. (1998). Linguistic complexity: locality of syntactic dependencies. *Cognition*, *68*(1), 1–76.

Gibson, Edward. (2000). The dependency locality theory: A distance-based theory of linguistic complexity. In A. Marantz, Y. Miyashita, & W. O'Neil (Eds.), *Image language brain Papers from the first mind articulation project symposium* (pp. 95–126). MIT Press.

Gibson, T. (1991). *A computational theory of human linguistic processing: Memory limitations and processing breakdown*.

Gisiger, T., Dehaene, S., & Changeux, J. P. (2000). Computational models of association cortex. *Current opinion in neurobiology*, *10*(2), 250–9.

Givón, T. (1982). Logic vs. Pragmatics, with human language as the referee: toward an empirically viable epistemology. *Journal of Pragmatics*, *6*(2), 81–133.

Goldman-Rakic, P. S., & Friedman, H. R. (1991). The circuitry of working memory revealed by anatomy and metabolic imaging. In H. S. Levin, H. M. Eisenberg, & A. L. Benton (Eds.), *Frontal Lobe Function and Dysfunction* (pp. 72–91). Oxford University Press.

Gordon, P. C., & Hendrick, R. (1997). Dimensions of Grammatical Coreference Coreference With Names and Pronouns.

Gorrell, P. (1995). Syntactic Analysis and Reanalysis in Sentence Processing. In Janet Dean Fodor & F. Ferreira (Eds.), *Reanalysis in Sentence Processing*. Dordrecht: Kluwer Academic Press.

Gouvea, A. C., Phillips, C., Kazanina, N., & Poeppel, D. (2010). The linguistic processes underlying the P600. *Language and Cognitive Processes*, *25*(2), 149–188.

Gray, C. M., König, P., Engel, A. K., & Singer, W. (1989). Oscillatory responses in cat visual cortex exhibit inter-columnar synchronization which reflects global stimulus properties. *Letters to Nature*, *338*, 334–337.

Grimm, S., Escera, C., Slabu, L., & Costa-Faidella, J. (2011). Electrophysiological evidence for the hierarchical organization of auditory change detection in the human brain. *Psychophysiology*, *48*(3), 377–84.

Grodzinsky, Y., & Friederici, A. D. (2006). Neuroimaging of syntax and syntactic processing. *Current opinion in neurobiology*, *16*(2), 240–6.

Gross, J, Kujala, J., Hamalainen, M., Timmermann, L., Schnitzler, a, & Salmelin, R. (2001). Dynamic imaging of coherent sources: Studying neural interactions in the human brain. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(2), 694–9.

Gross, J, Pollok, B., Dirks, M., Timmermann, L., Butz, M., & Schnitzler, a. (2005). Task-dependent oscillations during unimanual and bimanual movements in the human primary motor cortex and SMA studied with magnetoencephalography. *NeuroImage*, *26*(1), 91–8.

Gross, Joachim, Schmitz, F., Schnitzler, I., Kessler, K., Shapiro, K., Hommel, B., & Schnitzler, A. (2004). Modulation of long-range neural synchrony reflects temporal limitations of visual attention in humans. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(35), 13050–5.

Gross, M., Say, T., Kleingers, M., Clahsen, H., & Münte, T. F. (1998). *Human brain potentials to violations in morphologically complex Italian words. Neuroscience Letters* (Vol. 241, pp. 83–86). Elsevier.

Gunter, T. C., Friederici, a D., & Schriefers, H. (2000). Syntactic gender and semantic expectancy: ERPs reveal early autonomy and late interaction. *Journal of cognitive neuroscience*, *12*(4), 556–68.

Hagoort, P. (2003). How the brain solves the binding problem for language : a neurocomputational model of syntactic processing. *NeuroImage*, *20*, 18–29.

Hagoort, P. (2004). Integration of Word Meaning and World Knowledge in Language Comprehension. *Science*, *304*(438).

Hagoort, P. (2005). On Broca, brain, and binding: a new framework. *Trends Cogn Sci*, *9*(9), 416–423.

Hagoort, P., & Brown, C. (1994). Brain responses to lexical ambiguity resolution and parsing. In C. Clifton, L. Frazier, & K. Rayner (Eds.), *Perspectives on sentence processing* (pp. 45–81). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hagoort, P., & Brown, C. (2000). ERP effects of listening to speech : semantic ERP effects. *Neuropsychologia*, *38*, 1518–1530.

Hagoort, P., Brown, C., & Groothusen, J. (1993). The Syntactic Positive Shift ( SPS ) as an ERP Measure of Syntactic Processing. *Language*, (794410294).

Hahne, a, & Friederici, a D. (1999). Electrophysiological evidence for two steps in syntactic analysis. Early automatic and late controlled processes. *Journal of cognitive neuroscience*, *11*(2), 194–205.

Hahne, A., & Jescheniak, J. D. (2001). What's left if the Jabberwock gets the semantics? An ERP investigation into semantic and syntactic processes during auditory sentence comprehension. *Brain Research*, *11*(2), 199–212.

Hald, L. A., Bastiaansen, M. C. M., & Hagoort, P. (2006). EEG theta and gamma responses to semantic violations in online sentence processing. *Brain and Language*, *96*, 90–105.

Hanakawa, T., Honda, M., Sawamoto, N., Okada, T., Yonekura, Y., Fukuyama, H., & Shibasaki, H. (2002). The role of rostral Brodmann area 6 in mental-operation tasks: an integrative neuroimaging approach. *Cerebral cortex (New York, N.Y.: 1991)*, *12*(11), 1157–70.

Hankamer, J., & Sag, I. (1976). Deep and Surface Anaphora. *Linguistic Inquiry*, *7*(3), 391–426.

Hanslmayr, S., Aslan, A., Staudigl, T., Klimesch, W., Herrmann, C. S., & Bäuml, K.-H. (2007). Prestimulus oscillations predict visual perception performance between and within subjects. *NeuroImage*, *37*(4), 1465–73.

Hanslmayr, S., Gross, J., Klimesch, W., & Shapiro, K. L. (2011). The role of alpha oscillations in temporal attention. *Brain Research Reviews*, *67*(1-2), 331–343.

Hanslmayr, S., Spitzer, B., Bäuml, K.-H., & Ba, K. (2009). Brain oscillations dissociate between semantic and nonsemantic encoding of episodic memories. *Cerebral cortex (New York, N.Y. : 1991)*, *19*(7), 1631–40.

Hasting, A. S., & Kotz, S. A. (2008a). Speeding Up Syntax : On the Relative Timing and Automaticity of Local Phrase Structure and Morphosyntactic Processing as Reflected in Event-related Brain Potentials. *Journal of Cognitive Neuroscience*, 1207–1219.

Hasting, A. S., & Kotz, S. A. (2008b). Speeding Up Syntax : On the Relative Timing and Automaticity of Local Phrase Structure and Morphosyntactic Processing as Reflected in Event-related Brain Potentials. *Journal of Cognitive Neuroscience*, 1207–1219.

Hasting, A. S., Kotz, S. A., & Friederici, A. D. (2007). Setting the Stage for Automatic Syntax Processing: The Mismatch Negativity as an Indicator of Syntactic Priming. *Journal of cognitive neuroscience*, *19*(3), 386–400.

Haupt, F. S., Schlesewsky, M., Roehm, D., Friederici, A. D., & Bornkessel-Schlesewsky, I. (2008). The status of subject–object reanalyses in the language comprehension architecture. *Journal of Memory and Language*, *59*(1), 54–96.

Herten, M. V., Chwilla, D. J., & Kolk, H. H. J. (2006a). When Heuristics Clash with Parsing Routines : ERP Evidence for Conflict Monitoring in Sentence Perception. *Journal of Cognitive Neuroscience*, 1181–1197.

Herten, M. V., Chwilla, D. J., & Kolk, H. H. J. (2006b). When Heuristics Clash with Parsing Routines : ERP Evidence for Conflict Monitoring in Sentence Perception. *Journal of Cognitive Neuroscience*, *18*(7), 1181–1197.

Hickok, G., & Poeppel, D. (2000). Towards a functional neuroanatomy of speech perception. *Trends in Cognitive Sciences*, *4*(4), 131–138.

Hickok, G., & Poeppel, D. (2007). The cortical organization of speech processing. *Nature Reviews Neuroscience*, *8*, 393–402.

Holcomb, P. J. (1991). Natural speech processing : An analysis using event-related brain potentials, *19*(4), 286–300.

Howard, M. W., Rizzuto, D. S., Caplan, J. B., Madsen, J. R., Lisman, J., Aschenbrenner-Scheibe, R., Schulze-Bonhage, A., et al. (2003). Gamma oscillations correlate with working memory load in humans. *Cerebral cortex (New York, N.Y. : 1991)*, *13*(12), 1369–74.

Humphries, C., Binder, J. R., & Medler, D. A. (2006). Syntactic and Semantic Modulation of Neural Activity during Auditory Sentence Comprehension. *Journal of Cognitive Neuroscience*, 665–679.

Hämäläinen, M., Hari, R., Illmoniemi, R. J., Knuutila, J., & Lounasamaa, O. V. (1993). Magnetoencephalography theory, instrumentation, to noninvasive studies of the working human brain. *Review of Modern Physics*, *65*(2), 413–487.

Ikezawa, K., Ishii, R., Iwase, M., Kurimoto, R., Canuet, L., Takahashi, H., Nakahachi, T., et al. (2011). Decreased alpha event-related synchronization in the left posterior temporal cortex in schizophrenia: A magnetoencephalography-beamformer study. *Neuroscience research*, *71*(3), 235–43.

Ilkin, Z., & Sturt, P. (2011). Active prediction of syntactic information during sentence processing ∗. *Dialogue and Discourse*, *2*(1), 35–58.

Ille, N., Berg, P., & Scherg, M. (2002). Artifact Correction of the Ongoing EEG Using Spatial Filters Based on Artifact and Brain Signal Topographies. *Journal of Clinical Neurophysiology*, *19*(2), 113–124.

Indefrey, P., & Cutler, A. (2004). Prelexical and lexical processing in listening. In M. Gazzaniga (Ed.), *The cognitive neurosciences III* (pp. 759–774). Cambridge, MA: MIT Press.

Indefrey, P., & Levelt, W. J. M. (2004). The spatial and temporal signatures of word production components. *Cognition*, *92*(1-2), 101–144.

Isel, F., Hahne, A., Maess, B., & Friederici, A. D. (2007). Neurodynamics of sentence interpretation: ERP evidence from French. *Biological Psychology*, *74*(3), 337–346.

Jackendoff, R. (2007). *Language, Consciousness, Culture: Essays on Mental Structure. The Jean Nicod Lectures* (Vol. 2007, p. 431). MIT Press.

Jacobs, J., Hwang, G., Curran, T., & Kahana, M. J. (2006). EEG oscillations and recognition memory: theta correlates of memory retrieval and decision making. *NeuroImage*, *32*(2), 978–87.

January, D., Trueswell, J. C., & Thompson-schill, S. L. (2009). Co-localization of Stroop and Syntactic Ambiguity Resolution in Broca's Area: Implications for the Neural Basis of Sentence Processing. *J. Cogn. Neurosci.*, *21*(12), 2434–2444.

Jemel, B., George, N., Olivares, E., Fiori, N., & Renault, B. (1999). Event-related potentials to structural familiar face incongruity processing. *Psychophysiology*, *36*(4), 437–52.

Jensen, O., & Colgin, L. L. (2007). Cross-frequency coupling between neuronal oscillations. *Trends in Cognitive Sciences*, *11*(7), 267–269. Retrieved from

Jensen, O., Gelfand, J., Kounios, J., & Lisman, J. E. (2002). Oscillations in the alpha band (9-12 Hz) increase with memory load during retention in a short-term memory task. *Cerebral cortex (New York, N.Y.: 1991)*, *12*(8), 877–82.

Jensen, O., & Tesche, C. D. (2002). SHORT COMMUNICATION Frontal theta activity in humans increases with memory load in a working memory task, *15*, 1395–1399.

Jokisch, D., & Jensen, O. (2007). Modulation of gamma and alpha activity during a working memory task engaging the dorsal or ventral stream. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *27*(12), 3244–51.

Joshi, A. K., & Schabes, Y. (1997). Tree-Adjoining Grammars. In G. Rosenberg & A. Salomaa (Eds.), *Handbook of Formal Languages* (pp. 69–123). Berlin: Springer.

Just, M. a, & Carpenter, P. a. (1992). A capacity theory of comprehension: individual differences in working memory. *Psychological review*, *99*(1), 122–149.

Kaan, E, & Swaab, T. Y. (2003). Repair, revision and complexity in syntactic analysis: An electrophysiological differentiation. *Journal of Cognitive Neuroscience*, *15*, 98–110.

Kaan, Edith, Harris, A., Gibson, E., & Holcomb, P. (2000). The P600 as an index of syntactic integration dif culty. *Integration The Vlsi Journal*, *15*(2), 159–201.

Kaan, Edith, & Swaab, T. Y. (2002). The brain circuitry of syntactic comprehension. *Trends in cognitive sciences*, *6*(8), 350–356.

Kaan, Edith, & Swaab, T. Y. (2003). Repair , Revision , and Complexity in Syntactic Analysis : An Electrophysiological Differentiation. *Journal of Cognitive Neuroscience*, (1999), 98 – 110.

Kahana, M J, Seelig, D., & Madsen, J. R. (2001). Theta returns. *Current opinion in neurobiology*, *11*(6), 739–44.

Kahana, Michael J. (2006). The cognitive correlates of human brain oscillations. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *26*(6), 1669–72. d

Kaiser, J., & Lutzenberger, W. (2005). Human gamma-band activity: a window to cognitive processing. *NeuroReport*, *16*(3), 207–211.

Kandel, E. R., Schwartz, J. H., & Jessel, T. M. (1995). *Essentials of Neural Science and Behavior*. McGraw-Hill.

Kazanina, N., Lau, E. F., Lieberman, M., Yoshida, M., & Phillips, C. (2007). The effect of syntactic constraints on the processing of backwards anaphora. *Journal of Memory and Language*, *56*(3), 384–409.

Kennison, S. M., & Trofe, J. L. (2003). Comprehending pronouns: a role for word-specific gender stereotype information. *Journal of psycholinguistic research*, *32*(3), 355–78.

Kim, A., & Osterhout, L. (2005a). The independence of combinatory semantic processing : Evidence from event-related potentials. *Journal of Memory and Language*, *52*, 205–225.

Kim, A., & Osterhout, L. (2005b). The independence of combinatory semantic processing : Evidence from event-related potentials. *Journal of Memory and Language*, *52*, 205–225.

King, J., & Just, M. A. (1991). Individual differences in syntactic processing: The role of working memory. *Journal of Memory and Language*, *30*(5), 580–602. d

King, J. W., & Kutas, M. (1995). Who Did What and When? Using Word- and Clause-Level ERPs to Monitor Working Memory Usage in Reading. *Journal of Cognitive Neuroscience*, *7*(3), 376–395.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. *Brain research. Brain research reviews*, *29*(2-3), 169–95.

Klimesch, Wolfgang, Freunberger, R., Sauseng, P., & Gruber, W. (2008). A short review of slow phase synchronization and memory : Evidence for control processes in different memory systems? *Review Literature And Arts Of The Americas*, *5*.

Klimesch, Wolfgang, Sauseng, P., & Hanslmayr, S. (2007). EEG alpha oscillations: the inhibition-timing hypothesis. *Brain research reviews*, *53*(1), 63–88.

Kluender, R., & Kutas, M. (1993a). Subjacency as a processing phenomenon. *Language & Cognitive Processes*, *8*(4), 573–633.

Kluender, R., & Kutas, M. (1993b). Bridging the gap: Evidence from erps on the processing of unbounded dependencies. *Journal of cognitive neuroscience*, *5*(2), 196–214.

Koelsch, S., Gunter, T. C., Schröger, E., Tervaniemi, M., Sammler, D., & Friederici, a D. (2001). Differentiating ERAN and MMN: an ERP study. *Neuroreport*, *12*(7), 1385–9.

Kolk, H. H. J., Chwilla, D. J., Van Herten, M., & Oor, P. J. W. (2003). Structure and limited capacity in verbal working memory: a study with event-related potentials. *Brain and Language*, *85*(1), 1–36.

Kos, M., Vosse, T., van den Brink, D., & Hagoort, P. (2010). About Edible Restaurants: Conflicts between Syntax and Semantics as Revealed by ERPs. *Frontiers in psychology*, *1*(December), 222.

Kreiner, H., Sturt, P., & Garrod, S. (2008). Processing definitional and stereotypical gender in reference resolution: Evidence from eye-movements. *Journal of Memory and Language*, *58*(2), 239–261.

Kunde, W., Landgraf, F., Paelecke, M., & Kiesel, A. (2007). Dorsal and ventral processing under dual-task conditions. *Psychological science*, *18*(2), 100–4.

Kuperberg, G. (2007). Neural mechanisms of language comprehension: Challenges to syntax. *Brain Research*, *1146*, 23–49.

Kuperberg, G. R., Caplan, D., Eddy, M., & Holcomb, P. J. (2006). Neural correlates of processing syntactic , semantic, and thematic relationships in sentences. *Language and Cognitive Processes*, *21*(5), 489–530.

Kuperberg, G. R., Holcomb, P. J., Sitnikova, T., Greve, D., Dale, A. M., & Caplan, D. (2003). Distinct patterns of neural modulation during the processing of conceptual and syntactic anomalies. *Journal of cognitive neuroscience*, *15*(2), 272–93.

Kutas, M, & Federmeier, K. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in cognitive sciences*, *4*(12), 463–470.

Kutas, Marta, & Hillyard, S. A. (1980). Event related potentials in response to semantically inappropriate and surprisingly large words. *Biological Psychology*, *11*, 99–116.

Kutas, Marta, Van Petten, C. K., & Kluender, R. (2006). Psycholinguistics Electrified II ( 1994 – 2005 ). *Handbook of Psycholinguistics* (2nd Editio., pp. 659–724). Elsevier Inc.

König, P., & Schillen, T. B. (1991). Stimulus-Dependent Assembly Formation of Oscillatory Responses. *Neural Computation*, *3*, 155–166.

Laszlo, S., & Federmeier, K. D. (2009). A Beautiful Day in the Neighborhood: An Event-Related Potential Study of Lexical Relationships and Prediction in Context. *Journal of memory and language*, *61*(3), 326–338.

Lau, E., Stroud, C., Plesch, S., & Phillips, C. (2006). The role of structural prediction in rapid syntactic analysis. *Brain and language*, *98*(1), 74–88.

Ledoux, K., Traxler, M. J., & Swaab, T. Y. (2007). Syntactic Priming in Comprehension: Evidence from Event- Related Potentials. *Psychological Sciences*, *18*(2), 135–143.

Levelt, W. J., Roelofs, A., & Meyer, a S. (1999). A theory of lexical access in speech production. *The Behavioral and brain sciences*, *22*(1), 1–75.

Lewis, R. L. (n.d.). Reanalysis and Limited Repair Parsing: Leaping off the Garden Path, (1), 247–284.

Liljeström, M., Kujala, J., Jensen, O., & Salmelin, R. (2005). Neuromagnetic localization of rhythmic activity in the human brain: a comparison of three methods. *NeuroImage*, *25*(3), 734–745. R

Lisman, J. E., & Idiart, M. A. (1995). Storage of 7 +/- 2 short-term memories in oscillatory subcycles. *Science*, *267*(5203), 1512–1515.

Luck, S. J. (2005). *An Introduction to the Event-Related Potential Technique*. Cambridge, MA: MIT Press.

Luo, Y., Zhang, Y., Feng, X., & Zhou, X. (2010). Electroencephalogram oscillations differentiate semantic and prosodic processes during sentence reading. *Neuroscience*, *169*(2), 654–64.

Luu, P., Tucker, D. M., & Makeig, S. (2004). Frontal midline theta and the error-related negativity: neurophysiological mechanisms of action regulation. *Clinical Neurophysiology: official journal of the International Federation of Clinical Neurophysiology*, *115*(8), 1821–35.

MacDonald, M C, Just, M. A., & Carpenter, P. A. (1992). Working memory constraints on the processing of syntactic ambiguity. *Cognitive Psychology*, *24*(1), 56–98.

MacDonald, Maryellen C, & Christiansen, M. H. (2002). Reassessing working memory: A comment on Just & Carpenter (1992) and Waters & Caplan (1996). *Psychological Review*, *109*(1), 35–54.

Maris, E. (2004). Randomisation tests for ERP topographies and whole spatiotemporal data matrices. *Psychophysiology*, *41*(1), 142–151.

Maris, Eric, & Oostenveld, R. (2007). Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods*, *164*, 177–190.

Marslen-Wilson, W., & Tyler, L. K. (1980). The temporal structure of spoken language understanding. *Cognition*, *8*(1), 1–71.

Mason, R. a, Just, M. A., Keller, T. a, & Carpenter, P. a. (2003). Ambiguity in the brain: what brain imaging reveals about the processing of syntactically ambiguous sentences. *Journal of experimental psychology. Learning, memory, and cognition*, *29*(6), 1319–38.

McClelland, J. L., John, M. S., & Taraban, R. (1989). Sentence Comprehension: A Parallel Distributed Processing Approach. *Language and Cognitive Processes*, *4*, 287–335.

Mcrae, K., Spivey-Knowlton, M. J., & Tanenhaus, M. K. (1998). Modeling the Influence of Thematic Fit (and Other Constraints) in On-line Sentence C omprehension. *Journal of Memory and Language*, *38*, 283–312.

Meerendonk, N. V. D., Kolk, H. H. J., Vissers, C. T. W. M., & Chwilla, D. J. (2008). Monitoring in Language Perception : Mild and Strong Conflicts Elicit Different ERP Patterns. *Journal of Cognitive Neuroscience*, 1–16.

Meeuwissen, E. B., Takashima, A., Fernández, G., & Jensen, O. (2011). Evidence for human fronto-central gamma activity during long-term memory encoding of word sequences. *PloS one*, *6*(6), e21356.

Menon, V., Adleman, N. E., White, C. D., Glover, G. H., & Reiss, A. L. (2001). Error-related brain activation during a Go/NoGo response inhibition task. *Human Brain Mapping*, *12*(3), 131–143.

Meyer, L., Obleser, J., & Friederici, A. D. (2012). Left parietal alpha enhancement during working memory-intensive sentence processing. *Cortex*.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual review of neuroscience*, *24*, 167–202.

Molinaro, N., Kim, A., Vespignani, F., & Job, R. (2008). Anaphoric agreement violation: an ERP analysis of its interpretation. *Cognition*, *106*(2), 963–74.

Murphy, G. L. (1985). Processes of Understanding Anaphora. *Journal of Memory and Language*, *24*, 290–303.

Münte, T. F., & Heinze, H. J. (1994). Brain potentials reveal deficits of language processing after closed head injury. *Archives of Neurology*, *51*(5), 482–493

Neville, H. J., Nicol, J. L., Barss, A., Forster, K. I., & Garrett, M. F. (1991). Syntactically based processing classes: Evidence from eventrelated potentials. *Journal of Cognitive Neuroscience*, *3*, 151–165.

Nevins, A., Dillon, B., Malhotra, S., & Phillips, C. (2007). The role of feature-number and feature-type in processing Hindi verb agreement violations. *Brain research*, *1164*, 81–94.

Nichols, T. E., & Holmes, A. P. (2002). Nonparametric permutation tests for functional neuroimaging: a primer with examples. (K. Anderson, M. Domosh, N. Pile, & N. Thrift, Eds.)*Human Brain Mapping*, *15*(1), 1–25.

Nicol, J., & Swinney, D. (1989). The role of structure in coreference assignment during sentence comprehension. *Journal of Psycholinguistic Research*, *18*(1), 5–19.

Niedeggen, M., & Rösler, F. (1999). N400 Effects Reflect Activation Spread During Retrieval of Arithmetic Facts. *Psychological Science*, *10*(3), 271–276.

Niedeggen, M., Rösler, F., & Jost, K. (1999). Processing of incongruous mental calculation problems: evidence for an arithmetic N400 effect. *Psychophysiology*, *36*(3), 307–24.

Novick, J. M., Trueswell, J. C., & Thompson-Schill, S. L. (2005). Cognitive control and parsing: Reexamining the role of Broca's area in sentence comprehension. *Cognitive, Affective, & Behavioral Neuroscience*, *5*(3), 263–281.

Novick, Jared M., Trueswell, J. C., & Thompson-Schill, S. L. (2010). Broca's Area and Language Processing: Evidence for the Cognitive Control Connection. *Language and Linguistics Compass*, *4*(10), 906–924.

Nunez, P. (1981). *Electric Fields of the Brain: The Neurophysics of EEG*. New York: Oxford University Press.

Näätänen, R., Gaillard, A. W. K., & Mäntysalo. (1978). EARLY SELECTIVE-ATTENTION POTENTIAL ON EVOKED POTENTIAL REINTERPRETED*. *Acta psychologica*, *42*, 313–329.

Onton, J., Westerfield, M., Townsend, J., & Makeig, S. (2006). Imaging human EEG dynamics using independent component analysis. *Neuroscience & Biobehavioral Reviews*, *30*(6), 808–822.

Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J.-M. (2011). FieldTrip: Open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. *Computational intelligence and neuroscience*, *2011*(3).

Osterhout, L, Bersick, M., & McLaughlin, J. (1997). Brain potentials reflect violations of gender stereotypes. *Memory & cognition*, *25*(3), 273–85.

Osterhout, L, Holcomb, P. J., & Swinney, D. a. (1994). Brain potentials elicited by garden-path sentences: evidence of the application of verb information during parsing. *Journal of experimental psychology. Learning, memory, and cognition*, *20*(4), 786–803.

Osterhout, L. E. E., & Holcomb, P. J. (1992). Event-Related Brain Potentials Elicited by Syntactic Anomaly. *Journal of Memory and Language*, *806*, 785–806.

Osterhout, Lee, & Hagoort, P. (1999). A Superficial Resemblance Does Not Necessarily Mean You Are Part of the Family: Counterarguments to Coulson, King and Kutas (1998) in the P600/SPS-P300 Debate. *Language & Cognitive Processes*, *14*(1), 1–14.

Osterhout, Lee, Mclaughlin, J., Pitkänen, I., & Frenck-mestre, C. (2003). Novice learners, longitudinal designs, and event-related potentials: A means for exploring the neurocognition of second-language processing. *Language learning*, (56), 199–230.

Osterhout, Lee, & Mobley, L. A. (1995). Event-Related Brain Potentials Elicited by Failure to Agree. *Journal of Memory and Language*, *34*, 739–773.

Otten, M., & Van Berkum, J. (2008). Discourse-Based Word Anticipation During Language Processing: Prediction or Priming? *Discourse Processes*, *45*(6), 464–496.

Percival, D. B., & Walden, A. T. (1993). *Spectral Analysis for Physical Applications: Multitaper and Conventional Univariate Techniques. Cambridge Cambridge University Press* (Vol. 38, p. 583). Cambridge University Press.

Perrin, F., Pernier, J., Bertrand, O., & Echallier, J. F. (1989). Spherical splines for scalp potential and current density mapping. *Electroencephalography and Clinical Neurophysiology*, *72*(2), 184–187.

Petrides, M., & Pandya, D. N. (2002). Association pathways of the prefrontal cortex and functional observations. In D. T. Stuss & R. T. Knight (Eds.), *Principles of Frontal Lobe Function* (Vol. 1, pp. 31–50). Oxford University Press.

Petsche, H. (1998). *EEG and thinking : power and coherence analysis of cognitive processes*. Wien: Verl. der Österr. Akad. der Wissenschaften.

Pfurtscheller, G., & Berghold, a. (1989). Patterns of cortical activation during planning of voluntary movement. *Electroencephalography and clinical neurophysiology*, *72*(3), 250–8.

Pfurtscheller, G., & Da Silva, F. H. L. (1999). Event-related EEG/MEG synchronization and desynchronization: basic principles. *Clinical Neurophysiology*, *110*, 1842–1857.

Pfurtscheller, G., Neuper, C., Andrew, C., & Edlinger, G. (1997). Foot and hand area mu rhythms. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology*, *26*(1-3), 121–35.

Phillips, C., Kazanina, N., & Abada, S. H. (2005). ERP effects of the processing of syntactic long-distance dependencies. *Brain research. Cognitive brain research*, *22*(3), 407–28.

Phillips, C., & Wagers, M. (2007). Relating structure and time in linguistics and psycholinguistics. *The Oxford Handbook of Psycholinguistics* (pp. 739–756). Oxford University Press.

Piantoni, G. (2008). The time course of word category ambiguity processing: an MEG study. In B. Bloem (Ed.), *Proceedings of the Cognitive Neuroscience Master of Radboud University* (Vol. 37, pp. 33–50). Nijmegen: Nijmegen CNS.

Pickering, M. J., & Garrod, S. (2009). Reply Language , interaction and embodiment. *Language*, *1179*, 1178–1179.

Poldrack, R. A., Wagner, A. D., Prull, M. W., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. (1999). *Functional specialization for semantic and phonological processing in the left inferior prefrontal cortex. NeuroImage* (Vol. 10, pp. 15–35). Academic Press.

Posner, M I, & DiGirolamo, G. J. (1995). Attention in cognitive neuroscience: An overview. In M. S. Gazzaniga (Ed.), *The New Cognitive Neurosciences* (Vol. 1, pp. 623–631). MIT Press.

Posner, M I, & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*(1), 25–42.

Posner, M I, & Rothbart, M. K. (1998). Attention, self-regulation and consciousness. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *353*(1377), 1915–27.

Posner, Michael I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual review of psychology*, *58*, 1–23.

Posner, Michael I., & Snyder, C. R. R. (1975). Attention and cognitive control. In R. Solso (Ed.), *Information Processing and Cognition The Loyola Symposium* (pp. 55–85). Lawrence Earlbaum.

Pulvermüller, F., & Shtyrov, Y. (2003). Automatic processing of grammar in the human brain as revealed by the mismatch negativity. *NeuroImage*, *20*(1), 159–172.

Raghavachari, S., Kahana, M. J., Rizzuto, D. S., Caplan, J. B., Kirschen, M. P., Bourgeois, B., Madsen, J. R., et al. (2001). Gating of human theta oscillations by a working memory task. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *21*(9), 3175–83.

Raichle, M. E., MacLeod, a M., Snyder, a Z., Powers, W. J., Gusnard, D. a, & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(2), 676–82.

Rayner, K., Carlson, M., & Frazier, L. (1983). The Interaction of Syntax and Semantics During Sentence Processing : Eye Movements in the Analysis of Semantically Biased Sentences. *JOURNAL OF VERBAL LEARNING AND VERBAL BEHAVIOR*, *374*(22), 358–374.

Reinhart, T., & Reuland, E. (1993). Reflexivity. *Linguistic Inquiry*, *24*, 657–720.

Rodriguez, E., & George, N. (1999). Perception's shadow: long- distance synchronization of human brain activity, *397*(February).

Roehm, D., Schlesewsky, C. A. M., Bornkessel, I., Frisch, S., & Haider, H. (2004). Fractionating language comprehension via frequency characteristics of the human EEG. *Language*, *15*(3), 409–412.

Roelofs, A., & Hagoort, P. (2002). Control of language use: cognitive modeling of the hemodynamics of Stroop task performance. *Brain research. Cognitive brain research*, *15*(1), 85–97.

Rossi, S., Gugler, M. F., Hahne, A., & Friederici, A. D. (2005). When word category information encounters morphosyntax: an ERP study. *Neurosci. Lett.*, *384*, 228–233.

Ruchkin, D. S., Sutton, S., & Tueting, P. (1975). Emitted and Evoked P300 Potentials and Variation in Stimulus Probability. *Psychophysiology*, *12*(5), 591–595.

Rypma, B., & D'Esposito, M. (1999). The roles of prefrontal brain regions in components of working memory: Effects of memory load and individual differences. *Proceedings of the National Academy of Sciences of the United States of America*, *96*(11), 6558–6563.

Röhm, D, Klimesch, W., Haider, H., Doppelmayr, M., & Roehm, D. (2001). The role of theta and alpha oscillations for language comprehension in the human electroencephalogram. *Neuroscience letters*, *310*(2-3), 137–40.

Röhm, Dietmar. (2004). *Waves and Words: Oscillatory activity and language processing*. Philipps-Universität Marburg.

Salmelin, R, & Hari, R. (1994). Characterization of spontaneous MEG rhythms in healthy adults. *Electroencephalography and clinical neurophysiology*, *91*(4), 237–48.

Salmelin, Riitta, & Kujala, J. (2006). Neural representation of language: activation versus long-range connectivity. *Trends in cognitive sciences*, *10*(11), 519–25. 7

Sanford, T., & Garrod, S. C. (1989). What, when and how? Questions of immediacy in anaphoric reference resolution. *Language and Cognitive Processes*, *4*, 235–262.

Sarnthein, J., Petsche, H., Rappelsberger, P., Shaw, G. L., & von Stein, a. (1998). Synchronization between prefrontal and posterior association cortex during human working memory. *Proceedings of the National Academy of Sciences of the United States of America*, *95*(12), 7092–6.

Sauseng, P., Griesmayr, B., Freunberger, R., & Klimesch, W. (2010). Control mechanisms in working memory: a possible function of EEG theta oscillations. *Neuroscience and biobehavioral reviews*, *34*(7), 1015–22.

Sauseng, P., & Klimesch, W. (2008). Neuroscience and Biobehavioral Reviews What does phase information of oscillatory brain activity tell us about cognitive processes ? *Biobehavioral Reviews*, *32*, 1001–1013.

Scheeringa, R., Bastiaansen, M. C. M., Petersson, K. M., Oostenveld, R., Norris, D. G., & Hagoort, P. (2008). Frontal theta EEG activity correlates negatively with the default mode network in resting state. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology*, *67*(3), 242–51.

Schmitt, B. M., Lamers, M., & Münte, T. F. (2002). Electrophysiological estimates of biological and syntactic gender violation during pronoun processing. *Brain research. Cognitive brain research*, *14*(3), 333–46.

Schneider, S. (2007). Yes , It Does: A Diatribe on Jerry Fodor's The Mind Doesn't Work that Way. *PSYCHE*, *13*(1), 1–15.

Schnitzler, A., & Gross, J. (2005). Normal and pathological oscillatory communication in the brain. *Nature Reviews Neuroscience*, *6*(4), 285–96 .

Schurmann, M., Basar, E., Schürmann, M., Demiralp, T., Basar-Eroglu, C., & Ademoglu, A. (2001). Event-related oscillations are " real brain responses " - wavelet analysis and new strategies. *International Journal of Psychophysiology*, *39*, 91–127.

Shimamura, A. P. (1995). Memory and frontal lobe function. In Michael S Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 803–813). Cambridge, MA: MIT Press.

Shtyrov, Y., Pulvermüller, F., Näätänen, R., & Ilmoniemi, R. J. (2003). Grammar processing outside the focus of attention: an MEG study. *Journal of cognitive neuroscience*, *15*(8), 1195–206.

Singer, Wolf, & Gray, C. M. (1995). INTEGRATION AND THE TEMPORAL CORRELATION HYPOTHESIS. *Annual review of neuroscience*, *18*, 555–586.

Singer, Wolfgang. (1993). Synchronization of cortical activity and its putative role in information processing and learning, *Annu Rev P*(55), 349–374.

Singer, Wolfgang. (1999). Neuronal synchrony: a versatile code for the definition of relations? *Neuron*, *24*(49-65), 111–125.

Smith, E. E., & Jonides, J. (1999). Frontal Lobes, *283*(MARCH), 1657–1661.

Sprouse, J., & Lau, E. F. (2012). Syntax and the Brain. *The Cambridge Handbook of Generative Syntax*. Cambridge University Press, UK.

Steinhauer, K., & Drury, J. E. (2011). On the early left-anterior negativity (ELAN) in syntax studies. *Brain and language*, 1–28.

Stowe, L, Haverkort, M., & Zwarts, F. (2005). Rethinking the neurological basis of language. *Lingua*, *115*(7), 997–1042.

Stowe, L. A. (1984). *Models of Gap-Location in the Human Language Processor*. University of Rochester.

Stowe, Laurie a, Paans, A. M. J., Wijers, A. a, & Zwarts, F. (2004). Activations of "motor" and other non-language structures during sentence comprehension. *Brain and language*, *89*(2), 290–9.

Strüber, D., Basar-Eroglu, C., Hoff, E., & Stadler, M. (2000). Reversal-rate dependent differences in the EEG gamma-band during multistable visual perception. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology*, *38*(3), 243–52.

Sturt, P. (2010). The time-course of the application of binding constraints in reference resolution. *Journal of Memory and Language*, *48*(3), 542–562.

Swaab, T. Y., Camblin, C. C., & Gordon, P. C. (2004). Electrophysiological evidence for reversed lexical repetition effects in language processing. *Journal of Cognitive Neuroscience*, *16*(5), 715–726.

Tallon-Baudry, C, & Bertrand, O. (1999). Oscillatory gamma activity in humans and its role in object representation. *Trends in cognitive sciences*, *3*(4), 151–162.

Tallon-Baudry, C, Bertrand, O., & Fischer, C. (2001). *Oscillatory synchrony between human extrastriate areas during visual short-term memory maintenance. Journal of Neuroscience* (Vol. 21, p. RC177).

Tallon-Baudry, C, Kreiter, a, & Bertrand, O. (1999). Sustained and transient oscillatory responses in the gamma and beta bands in a visual short-term memory task in humans. *Visual neuroscience*, *16*(3), 449–59.

Tallon-Baudry, Catherine, Bertrand, O., Hénaff, M.-A., Isnard, J., & Fischer, C. (2005). *Attention modulates gamma-band oscillations differently in the human lateral occipital cortex and fusiform gyrus. Cerebral Cortex* (Vol. 15, pp. 654–662).

Tallon-baudry, C. (2009). Rhythms in Cognitive Processing. Language and Cognitive Processes. 26(9). 1317-1337.

Tanaka, S., Honda, M., & Sadato, N. (2005). Modality-specific cognitive function of medial and lateral human Brodmann area 6. *Journal of Neuroscience*, *25*(2), 496–501.

Thornhill, D. E., & Van Petten, C. (2012). Lexical versus conceptual anticipation during sentence processing: frontal positivity and N400 ERP components. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology*, *83*(3), 382–92.

Thut, G., Nietzel, A., Brandt, S. a, & Pascual-Leone, A. (2006). Alpha-band electroencephalographic activity over occipital cortex indexes visuospatial attention bias and predicts visual target detection. *The Journal of neuroscience: the official journal of the Society for Neuroscience*, *26*(37), 9494–502.

Tooley, K. M., Traxler, M. J., & Swaab, T. Y. (2009). Electrophysiological and behavioral evidence of syntactic priming in sentence comprehension. *Journal of experimental psychology. Learning, memory, and cognition*, *35*(1), 19–45.

Traxler, M. J., & Pickering, M. J. (1996). Plausibility and the Processing of Unbounded Dependencies:An Eye-Tracking Study. *Journal of Memory and Language*, *35*(3), 454–475.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic Influences on Parsing: Use of Thematic Role Information in Syntactic Ambiguity Resolution. *Journal of Memory and Language*, *33*, 285–318.

Tucker, D., Luu, P., Frishkoff, G., Quiring, J., & Poulsen, C. (2003). Frontolimbic response to negative feedback in clinical depression. *J Abnorm Psychol*, *112*(4), 667–678.

Tuladhar, A. M., Ter Huurne, N., Schoffelen, J.-M., Maris, E., Oostenveld, R., & Jensen, O. (2007). Parieto-occipital sources account for the increase in alpha activity with working memory load. *Human Brain Mapping*, *28*(8), 785–792.

Uhlhaas, P. J., Haenschel, C., Nikolić, D., & Singer, W. (2008). The role of oscillations and synchrony in cortical networks and their putative relevance for the pathophysiology of schizophrenia. *Schizophrenia bulletin*, *34*(5), 927–43.

Uhlhaas, P. J., Pipa, G., Lima, B., Melloni, L., Neuenschwander, S., Nikolic, D., & Lin, S. (2009). Neural synchrony in cortical networks: history, concept and current status. *Neuroscience*, *3*(July), 1–19.

Van Berkum, Jos J A, Brown, C., & Hagoort, P. (1999). Early Referential Context Effects in Sentence Processing: Evidence from Event-Related Brain Potentials. *Journal of Memory and Language*, *41*(2), 147–182.

Van Berkum, Jos J. A., Zwitserlood, P., Hagoort, P., & Brown, C. M. (2003). When and how do listeners relate a sentence to the wider discourse? Evidence from the N400 effect. *Cognitive Brain Research*, *17*, 701–718.

Van Berkum, J. J. a, Brown, C. M., Zwitserlood, P., Kooijman, V., & Hagoort, P. (2005). Anticipating upcoming words in discourse: evidence from ERPs and reading times. *Journal of experimental psychology. Learning, memory, and cognition*, *31*(3), 443–67.

Van Dijk, K. R. a, Hedden, T., Venkataraman, A., Evans, K. C., Lazar, S. W., & Buckner, R. L. (2010). Intrinsic functional connectivity as a tool for human connectomics: theory, properties, and optimization. *Journal of neurophysiology*, *103*(1), 297–321.

Van Petten, C, & Rheinfelder, H. (1995). Conceptual relationships between spoken words and environmental sounds: event-related brain potential measures. *Neuropsychologia*, *33*(4), 485–508. R

Van Petten, Cyma, & Luka, B. J. (2012). Prediction during language comprehension: benefits, costs, and ERP components. *International journal of psychophysiology : official journal of the International Organization of Psychophysiology*, *83*(2), 176–90.

Varela, F., Lachaux, J., Rodriguez, E., & Martinerie, J. (2001). THE BRAINWEB: PHASE LARGE-SCALE INTEGRATION. *Neuroscience*, *2*(April), 229–239.

Vidal, J. R., Chaumon, M., O'Regan, J. K., & Tallon-Baudry, C. (2006). Visual grouping and the focusing of attention induce gamma-band oscillations at different frequencies in human magnetoencephalogram signals. *Journal of Cognitive Neuroscience*, *18*(11), 1850–1862.

Vincenzi, M. D., Job, R., Di Matteo, R., Angrilli, A., Penolazzi, B., Ciccarelli, L., & Vespignani, F. (2003). Differences in the perception and time course of syntactic and semantic violations. *Brain and Language*, *85*(2), 280–296.

Vos, S. H., Gunter, T. C., Schriefers, H., & Angela, D. (2001). Syntactic parsing and working memory : The effects of syntactic complexity, reading span, and concurrent load. *LANGUAGE AND COGNITIVE PROCESSES*, (January 2012), 37–41.

Vos, S. H., Gunter, T. C., Schriefers, H., & Angela, D. (2010). Language and Cognitive Processes Syntactic parsing and working memory: The effects of syntactic complexity, reading span, and concurrent load. *Cognition*, (April 2012), 37–41.

Vosse, T., & Kempen, G. (2000). Syntactic structure assembly in human parsing: a computational model based on competitive inhibition and a lexicalist grammar. *Cognition*, *75*(2), 105–43. R

Wager, T. D., & Smith, E. E. (2003). Neuroimaging studies of working memory: a meta-analysis. *Cognitive, affective & behavioral neuroscience*, *3*(4), 255–74.

Wassenaar, M., & Hagoort, P. (2007). Thematic role assignment in patients with Broca's aphasia: sentence-picture matching electrified. *Neuropsychologia*, *45*(4), 716–40.

Weber, K., & Lavric, A. (2008). Syntactic anomaly elicits a lexico-semantic (N400) ERP effect in the second language but not the first. *Psychophysiology*, *45*(6), 920–5.

Weiss, S, Mueller, H. M., Schack, B., King, J. W., Kutas, M., & Rappelsberger, P. (2005). Increased neuronal communication accompanying sentence comprehension. *Int J Psychophysiol*, *57*(2), 129–141.

Weiss, Sabine, & Mueller, H. M. (2003). The contribution of EEG coherence to the investigation of language. *Brain and Language*, *85*, 325–343.

Weiss, Sabine, & Mueller, H. M. (2012). "Too Many betas do not Spoil the Broth": The Role of Beta Brain Oscillations in Language Processing. *Frontiers in psychology*, *3*(June), 201.

Wicha, N. Y. Y., Bates, E. A., Moreno, E. M., & Kutas, M. (2003). Potato not Pope: human brain potentials to gender expectation and agreement in Spanish spoken sentences. *Neuroscience Letters*, *346*(3), 165–168.

Wicha, N. Y. Y., Moreno, E. M., & Kutas, M. (2004). Anticipating words and their gender: an event-related brain potential study of semantic integration, gender expectancy, and gender agreement in Spanish sentence reading. *Journal of cognitive neuroscience*, *16*(7), 1272–88.

Wyart, V., & Tallon-Baudry, C. (2008). Neural dissociation between visual awareness and spatial attention. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *28*(10), 2667–79.

Ye, Z., & Zhou, X. (2009). Executive control in language processing. *Neuroscience and biobehavioral reviews*, *33*(8), 1168–77.

de Lange, F. P., Jensen, O., Bauer, M., & Toni, I. (2008). Interactions between posterior gamma and frontal alpha/beta oscillations during imagined actions. *Frontiers in human neuroscience*, *2*(August), 7.

van Elk, M., van Schie, H. T., Hunnius, S., Vesper, C., & Bekkering, H. (2008). You'll never crawl alone: neurophysiological evidence for experience-dependent motor resonance in infancy. *NeuroImage*, *43*(4), 808–14.

van Elk, M., van Schie, H. T., Zwaan, R. A., & Bekkering, H. (2010). The functional role of motor activation in language processing: motor cortical oscillations support lexical-semantic retrieval. *NeuroImage*, *50*(2), 665–77.

van Gaal, S., de Lange, F. P., & Cohen, M. X. (2012). The role of consciousness in cognitive control and decision making. *Frontiers in human neuroscience*, *6*(May), 121.

van Gompel, R. P. G., & Liversedge, S. P. (2003). The influence of morphological information on cataphoric pronoun assignment. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*(1), 128–139.

van Herten, M., Kolk, H. H. J., & Chwilla, D. J. (2005). An ERP study of P600 effects elicited by semantic anomalies. *Brain research. Cognitive brain research*, *22*(2), 241–55.

van de Meerendonk, N., Indefrey, P., Chwilla, D. J., & Kolk, H. H. J. (2010). Monitoring in language perception: Electrophysiological and hemodynamic responses to spelling violations. *NeuroImage*, *54*(3), 2350–2363.

von Stein, a, & Sarnthein, J. (2000). Different frequencies for different scales of cortical integration: from local gamma to long range alpha/theta synchronization. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology*, *38*(3), 301–13.

## Appendix A

### A.1 Experimental Items Materials Experiment 1 (spoken syntactic garden-path sentences)

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| 1a) The child that was carried by the mother was asleep. |
| 1b) The child carried by the mother was asleep. |
| 2a) The barman that was served by the waitress was handsome. |
| 2b) The barman served by the waitress was handsome. |
| 3a) The correspondent that was interviewed by the newswoman was optimistic. |
| 3b) The correspondent interviewed by the newswoman was optimistic. |
| 4a) The manager that was fired by the client was upset. |
| 4b) The manager fired by the client was upset. |
| 5a) The attorney that was arrested by the police was devastated. |
| 5b) The attorney arrested by the police was devastated. |
| 6a) The lawyer that was hired by the company was confident. |
| 6b) The lawyer hired by the company was confident. |
| 7a) The tutor that was instructed by the secretary was tired. |
| 7b) The tutor instructed by the secretary was tired. |
| 8a) The boy that was frightened by the teacher was pale. |
| 8b) The boy frightened by the teacher was pale. |
| 9a) The burglar that was shot by the housewife was shocked. |
| 9b) The burglar shot by the housewife was shocked. |
| 10a) The priest that was interrogated by the policeman was suspicious. |
| 10b) The priest interrogated by the policeman was suspicious. |
| 11a) The farmer that was slaughtered by the terrorist was old. |
| 11b) The farmer slaughtered by the terrorist was old. |
| 12a) The suspect that was accused by the detective was scary. |
| 12b) The suspect accused by the detective was scary. |
| 13a) The Professor that was evaluated by the students was pessimistic. |
| 13b) The Professor evaluated by the students was pessimistic. |
| 14a) The prisoner that was punished by the detective was innocent. |
| 14b) The prisoner punished by the detective was innocent. |
| 15a) The artist studied by the neurologist was famous. |
| 15b) The artist that was studied by the neurologist was famous. |
| 16a) The singer that was worshipped by the teenager was bad-mannered. |
| 16b) The singer worshipped by the teenager was bad-mannered. |
| 17a) The politician that was kicked by the activist was injured. |

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| 17b) The politician kicked by the activist was injured. |
| 18a) The footballer that was taught by the coach was talented. |
| 18b) The footballer taught by the coach was talented. |
| 19a) The barrister that was convicted by the judge was guilty. |
| 19b) The barrister convicted by the judge was guilty. |
| 20a) The soldier that was terrorized by the officer was unshaved. |
| 20b) The soldier terrorized by the officer was unshaved. |
| 21a) The juror that was questioned by the examiner was nervous. |
| 21b) The juror questioned by the examiner was nervous. |
| 22a) The teacher that was lectured by the principal was drunk. |
| 22b) The teacher lectured by the principal was drunk. |
| 23a) The actress that was photographed by the reporter was flattered. |
| 23b) The actress photographed by the reporter was flattered. |
| 24a) The tiger that was chased by the zookeeper was dangerous. |
| 24b) The tiger chased by the zookeeper was dangerous. |
| 25a) The chef that was dismissed by the hotelier was furious. |
| 25b) The chef dismissed by the hotelier was furious. |
| 26a) The accountant that was investigated by the inspector was trustworthy. |
| 26b) The accountant investigated by the inspector was trustworthy. |
| 27a) The tourist that was searched by the bouncer was patient. |
| 27b) The tourist searched by the bouncer was patient. |
| 28a) The nurse that was examined by the coroner was dead. |
| 28b) The nurse examined by the coroner was dead. |
| 29a) The speaker that was invited by the scientist was late. |
| 29b) The speaker invited by the scientist was late. |
| 30a) The woman that was rescued by the lifeguard was shaken. |
| 30b) The woman rescued by the lifeguard was shaken. |
| 31a) The therapist that was hypnotized by the magician was shy. |
| 31b) The therapist hypnotized by the magician was shy. |
| 32a) The criminal that was tortured by the CIA was uncooperative. |
| 32b) The criminal tortured by the CIA was uncooperative. |
| 33a) The dean that was sentenced by the referee was bewildered. |
| 33a) The dean sentenced by the referee was bewildered. |
| 34a) The dentist that was cured by the physician was grateful. |
| 34b) The dentist cured by the physician was grateful. |
| 35a) The counsellor that was convicted by the jury was bald. |
| 35a) The counsellor convicted by the jury was bald. |
| 36a) The postgraduate that was graded by the examiner was petrified. |

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| 36b) The postgraduate graded by the examiner was petrified. |
| 37a) The girl that was lifted by the fireman was calm. |
| 37b) The girl lifted by the fireman was calm. |
| 38a) The presenter that was entertained by the comedian was experienced. |
| 38b) The presenter entertained by the comedian was experienced. |
| 39a) The model that was admired by the photographer was famous. |
| 39b) The model admired by the photographer was famous. |
| 40a) The housewife that was kissed by the milkman was pretty. |
| 40b) The housewife kissed by the milkman was pretty. |
| 41a) The grandmother that was remembered by her grandson was funny. |
| 41b) The grandmother remembered by her grandson was funny. |
| 42a) The student that was warned by the principal was cheeky. |
| 42b) The student warned by the principal was cheeky. |
| 43a) The horse that was explored by the vet was hurt. |
| 43b) The horse explored by the vet was hurt. |
| 44a) The child that was found by his mother was sleepy. |
| 44b) The child found by his mother was sleepy. |
| 45a) The banker that was murdered by the burglar was rich. |
| 45b) The banker murdered by the burglar was rich. |
| 46a) The politician that was persuaded by the vice-president was overconfident. |
| 46b) The politician persuaded by the vice-president was overconfident. |
| 47a) The nun that was convinced by the priest was faithful. |
| 47b) The nun convinced by the priest was faithful. |
| 48a) The driver that was stopped by the patrol was drunk. |
| 48b) The driver stopped by the patrol was drunk. |
| 49a) The builder that was instructed by the architect was skilled. |
| 49b) The builder instructed by the architect was skilled. |
| 50a) The chef that was helped by the assistant was grumpy. |
| 50b) The chef helped by the assistant was grumpy. |
| 51a) The basketball-player that was pushed by his rival was angry. |
| 51b) The basketball-player pushed by his rival was angry. |
| 52a) The demonstrator that was punched by the scientologist was ugly. |
| 52b) The demonstrator punched by the scientologist was ugly. |
| 53a) The receptionist that was assisted by the trainee was friendly. |
| 53b) The receptionist assisted by the trainee was friendly. |
| 54a) The economist that was tutored by the lecturer was bored. |
| 54b) The economist tutored by the lecturer was bored. |
| 55a) The hairdresser that was advised by his boss was compliant. |

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| 55b) The hairdresser advised by his boss was compliant. |
| 56a) The singer that was recorded by the producer was talented. |
| 56b) The singer recorded by the producer was talented. |
| 57a) The athlete that was trained by the manager was exhausted. |
| 57a) The athlete trained by the manager was exhausted. |
| 58a) The performer that was painted by his friend was enthusiastic. |
| 58a) The performer painted by his friend was enthusiastic. |
| 59a) The kitten that was loved by the schoolgirl was cute. |
| 59b) The kitten loved by the schoolgirl was cute. |
| 60a) The visitor that was expected by the director was friendly. |
| 60b) The visitor expected by the director was friendly. |
| 61a) The guide that was followed by the tourists was competent. |
| 61b) The guide followed by the tourists was competent. |
| 62a) The dictator that was hated by the people was cruel. |
| 62b) The dictator hated by the people was cruel. |
| 63a) The secretary that was intimidated by her boss was inept. |
| 63b) The secretary intimidated by her boss was inept. |
| 64a) The tax consultant that was recommended by the colleague was Scottish. |
| 64b) The tax consultant recommended by the colleague was Scottish. |
| 65a) The singer that was casted by the agency was talented. |
| 65b) The singer casted by the agency was talented. |
| 66a) The athlete who was trained by the instructor was exhausted. |
| 66b) The athlete trained by the instructor was exhausted. |
| 67a) The solicitor that was appointed by the hospital was too defensive. |
| 67b) The solicitor appointed by the hospital was too defensive. |
| 68a) The lawyer that was confused by the barrister was too defensive. |
| 68b) The lawyer confused by the barrister was too defensive. |
| 69a) The assistant that was embarrassed by the affair was very young. |
| 69b) The assistant embarrassed by the affair was very young. |
| 70a) The contestant that was teased by the judge was almost crying. |
| 70b) The contestant teased by the judge was almost crying. |
| 71a) The ambassador that was welcomed by the king was honoured. |
| 71b) The ambassador welcomed by the king was honoured. |
| 72a) The singer that was introduced by the musician was arrogant. |
| 72b) The singer introduced by the musician was arrogant. |
| 73a) The minister that was elected by the priest was delighted. |
| 73b) The minister elected by the priest was delighted. |
| 74a) The scientist that was rejected by the journal was fuming. |

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| 74b) The scientist rejected by the journal was fuming. |
| 75a) The shopkeeper that was injured by the robber was screaming. |
| 75b) The shopkeeper injured by the robber was screaming. |
| 76a) The sailor that was saved by the navy was deeply grateful. |
| 76b) The sailor saved by the navy was deeply grateful. |
| 77a) The sailor that was saved by the navy was deeply grateful. |
| 77b) The sailor saved by the navy was deeply grateful. |
| 78a) The agent that was monitored by the General was working for the CIA. |
| 78b) The agent monitored by the General was working for the CIA. |
| 79a) The Palestinian leader that was offended by the rabbi kept silent. |
| 79b) The Palestinian leader offended by the rabbi kept silent. |
| 80a) The wife that was quizzed by the police was rather nervous. |
| 80b) The wife quizzed by the police was rather nervous. |
| 81a) The cricket player that was angered by the referee was disrespectful. |
| 81b) The cricket player angered by the referee was disrespectful. |
| 82a) The editor that was impressed by the writer was easy to please. |
| 82b) The editor impressed by the writer was easy to please. |
| 83a) The girl that was cuddled by the mother was laughing. |
| 83b) The girl cuddled by the mother was laughing. |
| 84a) The journalist that was respected by the broadcaster was part of a big scandal. |
| 84b) The journalist respected by the broadcaster was part of a big scandal. |
| 85a) The bachelor that was adored by the actress was very handsome. |
| 85b) The bachelor adored by the actress was very handsome. |
| 86a) The cage fighter that was aggravated by the challenger was having trouble breathing. |
| 86b) The cage fighter aggravated by the challenger was having trouble breathing. |
| 87a) The food critic that was poisoned by the chef was rushed to hospital. |
| 87b) The food critic poisoned by the chef was rushed to hospital. |
| 88a) The prisoner that was removed by the warden was cheering loudly. |
| 88b) The prisoner removed by the warden was cheering loudly. |
| 89a) The salesman that was helped by the assistant was very surprised. |
| 89b) The salesman helped by the assistant was very surprised. |
| 90a) The Prime Minister that was nominated by the committee was feeling privileged. |
| 90b) The Prime Minister nominated by the committee was feeling privileged. |
| 91a) The secretary that was bullied by the colleagues was very unhappy. |
| 91b) The secretary bullied by the colleagues was very unhappy. |
| 92a) The priest that was influenced by the cardinal was rather old. |
| 92b) The priest influenced by the cardinal was rather old. |

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| 93a) The onlooker that was amused by the dancer was all smiles. |
| 93b) The onlooker amused by dancer was all smiles. |
| 94a) The contractor that was represented by the lawyer was not listening. |
| 94b) The contractor represented by the lawyer was not listening. |
| 95a) The actress that was dressed by the make-up artist looked quite ridiculous. |
| 95b) The actress dressed by the make-up artist looked quite ridiculous. |
| 96a) The enemy that was destroyed by the fleet was defeated. |
| 96b) The enemy destroyed by the fleet was defeated. |
| 97a) The shoplifter that was hunted by the sergeant was fast. |
| 97b) The shoplifter hunted by the sergeant was fast. |
| 98a) The accountant that was charged by the banker was stealing. |
| 98b) The accountant charged by the banker was stealing. |
| 99a) The boy that was attacked by the dog was frightened to death. |
| 99b) The boy  attacked by the dog was frightened to death. |
| 100a) The consultant that was called by the dentist was not available. |
| 100b) The consultant called by the salad was not available. |
| 101a) The child that was hugged by the nurse was much better again. |
| 101b) The child hugged by the nurse was much better again. |
| 102a) The hunter that was approached by the boar was very nervous. |
| 102b) The hunter approached by the boar was very nervous. |
| 103a) The pilgrim that was touched by the pope was over the moon. |
| 103b) The pilgrim touched by the pope was over the moon. |
| 104a) The model that was spotted by the scout was really pretty. |
| 104b) The model spotted by the scout was really pretty. |
| 105a) The plumber that was insulted by the busybody was very angry. |
| 105b) The plumber insulted by the busybody was very angry. |
| 106a) The old lady that was visited by the family was in good spirits. |
| 106b) The old lady visited by the family was in good spirits. |
| 107a) The eagle that was observed by the bird watcher very rare. |
| 107b) The eagle that was observed by the bird watcher very rare. |
| 108a) The apprentice boy that was hit by the butcher was crying. |
| 108b) The apprentice boy hit by the butcher was crying. |
| 109a) The banker that was confronted by the customer was known to be stubborn. |
| 109b) The banker confronted by the material was known to be stubborn. |
| 110a) The accountant that was killed by the burglar was immediately dead. |
| 110b) The accountant killed by the burglar was immediately dead. |
| 111a) The swimmer that was celebrated by the crowd was enjoying himself. |
| 111b) The swimmer celebrated by the crowd was enjoying himself. |

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| 112a) The dancer that was watched by the man was talented. |
| 112b) The dancer watched by the man was not talented. |
| 113a) The plumber who was robbed by the burglar was having a bad day. |
| 113b) The plumber who was robbed by the forearm was having a bad day. |
| 114a) The cowboy who was scared by the Indian was smelling of cheap whiskey. |
| 114b) The cowboy who was scared by the Indian was smelling of cheap whiskey. |
| 115a) The flight attendant that was complimented by the tourist was smiling. |
| 115b) The flight attendant complimented by the tourist was smiling. |
| 116a) The serviceman who was ignored by the officer was waiting patiently. |
| 116b) The serviceman who was ignored by the officer was waiting patiently. |
| 117a) The mother that was phoned by the school was very upset. |
| 117b) The mother phoned by the school was very upset. |
| 118a) The diplomat that was blackmailed by the mistress was not willing to pay the ransom. |
| 118b) The diplomat blackmailed by the mistress was not willing to pay the ransom. |
| 119a) The WAG that was seduced by the footballer was regretting it later. |
| 119b) The WAG seduced by the footballer was regretting it later. |
| 120a) The princess that was saluted by the citizens was shy. |
| 120b) The princess saluted by the citizens was shy. |
| 121a) The veteran that was thanked by the queen was extremely proud. |
| 121b) The veteran thanked by the queen was extremely proud. |
| 122a) The lecturer that was annoyed by the graduate was usually patient. |
| 122b) The lecturer annoyed by the graduate was usually patient. |
| 123a) The judge that was begged by the crook was not willing to compromise. |
| 123b) The judge begged by the crook was not willing to compromise. |
| 124a) The librarian that was shushed by the visitor was surprised. |
| 124b) The librarian shushed by with visitor was surprised. |
| 125a) The tennis player that was coached by the trainer was very committed. |
| 125b) The tennis player coached by the trainer was very committed. |
| 126a) The MP that was overruled by the queen was grudgingly responding. |
| 126b) The MP overruled by the queen was grudgingly responding. |
| 127a) The Governor that was censured by the parliament was allegedly corrupt. |
| 127b) The Governor censured by the parliament was allegedly corrupt. |
| 128a) The scriptwriter that was inspired by the author was happy to give him credit. |
| 128b) The scriptwriter inspired by the author was happy to give him credit. |

**A.2 Biosemi-64+4 Channel Layout (10-20 system)**
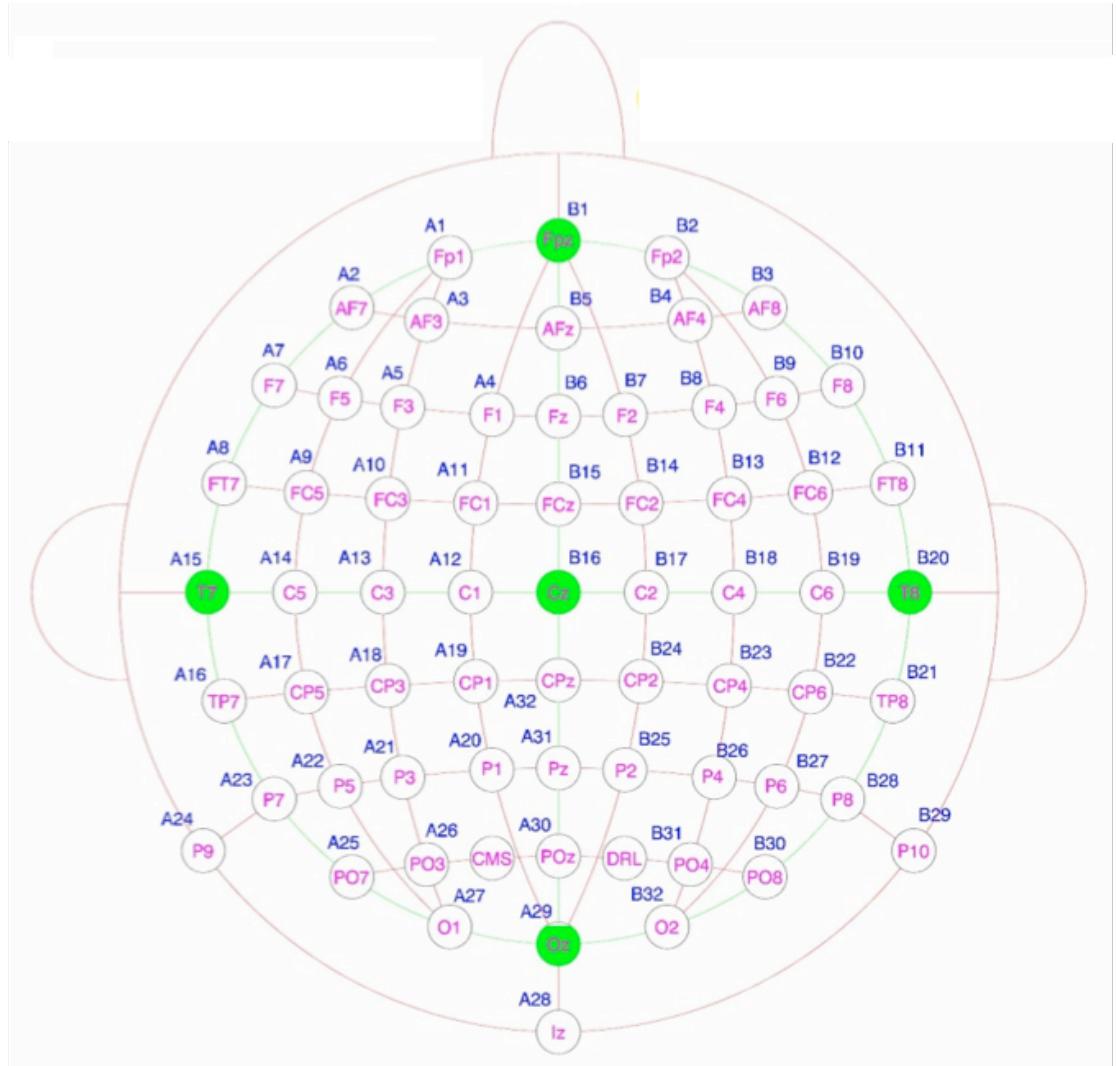
**Appendix B.**

## B.1 Experimental Items Anaphora

01 THE SHOT
The marksman aimed at the target after reassuring himself about the gun.
The marksman aimed at the target after reassuring herself about the gun.
The murderer aimed at the target after reassuring himself about the gun.
The murderer aimed at the target after reassuring herself about the gun.

02 HOMOCIDE
The marksman left the building after cleaning himself of all the blood.
The marksman left the building after cleaning herself of all the blood.
The murderer left the building after cleaning himself of all the blood.
The murderer left the building after cleaning herself of all the blood.

03 LOVE AFFAIR
The cowboy moved to Australia after convincing himself about the affair.
The cowboy moved to Australia after convincing herself about the affair.
The farmer moved to Australia after convincing himself about the affair.
The farmer moved to Australia after convincing herself about the affair.

04 WEATHER FORECAST
The cowboy gathered the herd after reminding himself about the forecast.
The cowboy gathered the herd after reminding herself about the forecast.
The farmer gathered the herd after reminding himself about the forecast.
The farmer gathered the herd after reminding herself about the forecast.

05 THE FIGHT
The barman cleared the atmosphere after tormenting himself over the fight.
The barman cleared the atmosphere after tormenting herself over the fight.
The jailer cleared the atmosphere after tormenting himself over the fight.
The jailer cleared the atmosphere after tormenting herself over the fight.

06 DRINKING PROBLEM
The barman prepared another drink while convincing himself it's the last one.
The barman prepared another drink while convincing herself it's the last one.
The jailer prepared another drink while convincing himself it's the last one.
The jailer prepared another drink while convincing herself it's the last one.

07 UNEXPECTED FINDINGS
The foreman considered alternative explanations while convincing himself about the findings.
The foreman considered alternative explanations while convincing herself about the findings.
The explorer considered alternative explanations while convincing himself about the findings.
The explorer considered alternative explanations while convincing herself about the findings.

08 PAINFUL DECISION
The foreman decided to suspend the project after familiarising himself with the report.
The foreman decided to suspend the project after familiarising herself with the report.
The explorer decided to suspend the project after familiarising himself with the report.
The explorer decided to suspend the project after familiarising herself with the report.

## 09 SUSPICIONS
The policeman investigated the story after reminding himself about the suspicious questions.
The policeman investigated the story after reminding herself about the suspicious questions.
The constable investigated the story after reminding himself about the suspicious questions.
The constable investigated the story after reminding herself about the suspicious questions.

## 10 DRUG DEAL
The policeman entered the building after convincing himself about the drug deal.
The policeman entered the building after convincing herself about the drug deal.
The constable entered the building after convincing himself about the drug deal.
The constable entered the building after convincing herself about the drug deal.

## 11 FIRE IN THE BUILDING
The fireman was restless after pulling himself out of the fire.
The fireman was restless after pulling herself out of the fire.
The fire-fighter was restless after pulling himself out of the fire.
The fire-fighter was restless after pulling herself out of the fire.

## 12 THE CAT
The fireman climbed to the roof after reminding himself about the little cat.
The fireman climbed to the roof after reminding herself about the little cat.
The fire-fighter climbed to the roof after reminding himself about the little cat.
The fire-fighter climbed to the roof after reminding herself about the little cat.

## 13 ON THE HIJACKED PLANE
The spokesman moved the bomb while putting himself on the line.
The spokesman moved the bomb while putting herself on the line.
The pilot moved the bomb while putting himself on the line.
The pilot moved the bomb while putting herself on the line.

## 14 NEW REGULATIONS
The spokesman explained the security procedures after reminding himself about the new regulations.
The spokesman explained the security procedures after reminding herself about the new regulations.
The pilot explained the security procedures after reminding himself about the new regulations.
The pilot explained the security procedures after reminding herself about the new regulations.

## 15 AN IMPORTANT LETTER
The businessman came to the meeting after reminding himself about the letter.
The businessman came to the meeting after reminding herself about the letter.
The minister came to the meeting after reminding himself about the letter.
The minister came to the meeting after reminding herself about the letter.

## 16 TAX INVESTIGATION
The businessman drank a cup of coffee while preparing himself for the tax inquiry.
The businessman drank a cup of coffee while preparing herself for the tax inquiry.
The minister drank a cup of coffee while preparing himself for the tax inquiry.
The minister drank a cup of coffee while preparing herself for the tax inquiry.

## 17 MORNING IN TOWN
The gentleman found the new shop after familiarising himself with the directions.
The gentleman found the new shop after familiarising herself with the directions.
The driver found the new shop after familiarising himself with the directions.
The driver found the new shop after familiarising herself with the directions.

18 THE ACCIDENT
The gentleman asked for medical assistance after hurting himself in a car accident.
The gentleman asked for medical assistance after hurting herself in a car accident.
The driver asked for medical assistance after hurting himself in a car accident.
The driver asked for medical assistance after hurting herself in a car accident.

19 BUISNESS COMPETITION
The salesman became ill after working himself into frenzy yesterday.
The salesman became ill after working herself into frenzy yesterday.
The tailor became ill after working himself into frenzy yesterday.
The tailor became ill after working herself into frenzy yesterday.

20 DEMAND FOR MORE MONEY
The salesman demanded more money after arming himself with a formal letter.
The salesman demanded more money after arming herself with a formal letter.
The tailor demanded more money after arming himself with a formal letter.
The tailor demanded more money after arming herself with a formal letter.

21 REGULATIONS
The chairman performed the necessary procedures after reminding himself about the regulations.
The chairman performed the necessary procedures after reminding herself about the regulations.
The surgeon performed the necessary procedures after reminding himself about the regulations.
The surgeon performed the necessary procedures after reminding herself about the regulations.

22 NEW MEDICINE
The chairman recommended the new medicine after reassuring himself about the side effects.
The chairman recommended the new medicine after reassuring herself about the side effects.
The surgeon recommended the new medicine after reassuring himself about the side effects.
The surgeon recommended the new medicine after reassuring herself about the side effects.

23 ON EASTER
The uncle came to visit again after enjoying himself so much at Christmas.
The uncle came to visit again after enjoying herself so much at Christmas.
The scout came to visit again after enjoying himself so much at Christmas.
The scout came to visit again after enjoying herself so much at Christmas.

24 CAMPING NIGHTMARE
The uncle went to sleep in the car after tormenting himself in the tent.
The uncle went to sleep in the car after tormenting herself in the tent.
The scout went to sleep in the car after tormenting himself in the tent.
The scout went to sleep in the car after tormenting herself in the tent.


25 THE PARTY
The bachelor promised to come after reminding himself about last year's party.
The bachelor promised to come after reminding herself about last year's party.
The clown promised to come after reminding himself about last year's party.
The clown promised to come after reminding herself about last year's party.

26 A SUCCESSFUL SHOW
The bachelor agreed to participate in the show after reminding himself of last year's success.
The bachelor agreed to participate in the show after reminding herself of last year's success.
The clown agreed to participate in the show after reminding himself of last year's success.
The clown agreed to participate in the show after reminding herself of last year's success.

## 27 BUSINESS TRIPS
The father brought home many presents after upsetting himself about the long separation.
The father brought home many presents after upsetting herself about the long separation.
The inventor brought home many presents after upsetting himself about the long separation.
The inventor brought home many presents after upsetting herself about the long separation.

## 28 BRILLIANT SOLUTIONS
The father had brilliant ideas after reassuring himself about finding a solution.
The father had brilliant ideas after reassuring herself about finding a solution.
The inventor had brilliant ideas after reassuring himself about finding a solution.
The inventor had brilliant ideas after reassuring herself about finding a solution.

## 29 DISAPPOINTMENT
The sportsman couldn't take part in the match after injuring himself during training.
The sportsman couldn't take part in the match after injuring himself during training.
The footballer couldn't take part in the match after injuring himself during training.
The footballer couldn't take part in the match after injuring himself during training.

## 30 MOTIVATION
The sportsman was highly motivated after promising himself to break the record.
The sportsman was highly motivated after promising herself to break the record.
The footballer was highly motivated after promising himself to break the record.
The footballer was highly motivated after promising herself to break the record.

## 31 SHOOTING IN AFRICA
The cameraman accepted the offer after convincing himself about the important publication.
The cameraman accepted the offer after convincing herself about the important publication.
The photographer accepted the offer after convincing himself about the important publication.
The photographer accepted the offer after convincing herself about the important publication.

## 32 FASHION SHOW IN AUSTRALIA
The cameraman agreed to the location after reminding himself about the wonderful beaches.
The cameraman agreed to the location after reminding herself about the wonderful beaches.
The photographer agreed to the location after reminding himself about the wonderful beaches.
The photographer agreed to the location after reminding herself about the wonderful beaches.

## 33 FAMILY MEETINGS
The nephew decided to come after convincing himself about the importance of family meetings.
The nephew decided to come after convincing herself about the importance of family meetings.
The General decided to come after convincing himself about the importance of family meetings.
The General decided to come after convincing herself about the importance of family meetings.

## 34 HOME SWEET HOME
The nephew decided to leave the army after convincing himself to return home.
The nephew decided to leave the army after convincing herself to return home.
The General decided to leave the army after convincing himself to return home.
The General decided to leave the army after convincing herself to return home.

## 35 COURT ORDER
The stepfather never came near the house again after reminding himself about the court order.
The stepfather never came near the house again after reminding herself about the court order.
The killer never came near the house again after reminding himself about the court order.
The killer never came near the house again after reminding herself about the court order.

## 36 IN THE LOCAL PUB
The stepfather was arrested after injuring himself in the local pub.
The stepfather was arrested after injuring herself in the local pub.
The killer was arrested after injuring himself in the local pub.
The killer was arrested after injuring herself in the local pub.

## 37 BROKEN GLASS
The schoolboy was more careful after cutting himself with broken glass.
The schoolboy was more careful after cutting herself with broken glass.
The magician was more careful after cutting himself with broken glass.
The magician was more careful after cutting herself with broken glass.

## 38 MAGIC CARDS
The schoolboy gave a wonderful magic show after teaching himself some new card tricks.
The schoolboy gave a wonderful magic show after teaching herself some new card tricks.
The magician gave a wonderful magic show after teaching himself some new card tricks.
The magician gave a wonderful magic show after teaching herself some new card tricks.

## 39 CRISIS AT WORK
The husband thought about the crisis while pouring himself a glass of Whisky.
The husband thought about the crisis while pouring herself a glass of Whisky.
The director thought about the crisis while pouring himself a glass of Whisky.
The director thought about the crisis while pouring herself a glass of Whisky.

## 40 A DREAM COMES TRUE
The husband decided to retire after promising himself to buy a yacht.
The husband decided to retire after promising herself to buy a yacht.
The director decided to retire after promising himself to buy a yacht.
The director decided to retire after promising herself to buy a yacht.

## 41 LOVE AND CHOCOLATES
The boyfriend sent chocolates after deluding himself about the love affair.
The boyfriend sent chocolates after deluding herself about the love affair.
The trucker sent chocolates after deluding himself about the love affair.
The trucker sent chocolates after deluding herself about the love affair.

## 42 TRUE LOVE
The boyfriend sent a sentimental letter after convincing himself about being in love.
The boyfriend sent a sentimental letter after convincing herself about being in love.
The trucker sent a sentimental letter after convincing himself about being in love.
The trucker sent a sentimental letter after convincing herself about being in love.

## 43 AN ACCIDENT IN THE WOODS
The son desperately wanted to go home after injuring himself with an axe.
The son desperately wanted to go home after injuring herself with an axe.
The logger desperately wanted to go home after injuring himself with an axe.
The logger desperately wanted to go home after injuring herself with an axe.

## 44 PROTECTING THE ROBIN
The son worried about cutting the tree after reminding himself about the robin's nest.
The son worried about cutting the tree after reminding herself about the robin's nest.
The logger worried about cutting the tree after reminding himself about the robin's nest.
The logger worried about cutting the tree after reminding herself about the robin's nest.

## 45 POVERTY AND COMPASSION
The landlord didn't raise the rental fee after reminding himself of the circumstances.
The landlord didn't raise the rental fee after reminding herself of the circumstances.
The executive didn't raise the rental fee after reminding himself of the circumstances.
The executive didn't raise the rental fee after reminding herself of the circumstances.

## 46 REFURBISHMENTS
The landlord refurbished the apartments after convincing himself about the low costs.
The landlord refurbished the apartments after convincing herself about the low costs.
The executive refurbished the apartments after convincing himself about the low costs.
The executive refurbished the apartments after convincing herself about the low costs.

## 47 IN THE NEIGHBOURHOOD
The milkman left the neighbourhood after finding himself out of job.
The milkman left the neighbourhood after finding herself out of job.
The butcher left the neighbourhood after finding himself out of job.
The butcher left the neighbourhood after finding herself out of job.

## 48 CLOSING THE BUSINESS
The milkman decided to close down after reminding himself of the low profits.
The milkman decided to close down after reminding herself of the low profits.
The butcher decided to close down after reminding himself of the low profits.
The butcher decided to close down after reminding herself of the low profits.

## 49 THE NEW PROJECT
The congressman supported all actions after persuading himself about the project.
The congressman supported all actions after persuading herself about the project.
The senator supported all actions after persuading himself about the project.
The senator supported all actions after persuading herself about the project.

## 50 DAMAGE CONTROL
The congressman tried to prevent the publication after picturing to himself the potential consequences.
The congressman tried to prevent the publication after picturing to herself the potential consequences.
The senator tried to prevent the publication after picturing to himself the potential consequences.
The senator tried to prevent the publication after picturing to herself the potential consequences.

## 51 FAMILY BUSINESS
The brother left the family business after convincing himself to open a restaurant.
The brother left the family business after convincing herself to open a restaurant.
The chef left the family business after convincing himself to open a restaurant.
The chef left the family business after convincing herself to open a restaurant.

## 52 COOKING SKILLS
The brother cooked a dreadful meal after praising himself arrogantly for years.
The brother cooked a dreadful meal after praising herself arrogantly for years.
The chef cooked a dreadful meal after praising himself arrogantly for years.
The chef cooked a dreadful meal after praising herself arrogantly for years.

## 53 HAZARDOUS TOOLS
The man carefully checked all the tools after hurting himself with the rusty scissors.
The man carefully checked all the tools after hurting herself with the rusty scissors.
The barber carefully checked all the tools hurting himself with the rusty scissors.
The barber carefully checked all the tools hurting herself with the rusty scissors.

## 54 NEW ELECTRIC RAZOR
The man read the instructions while cautioning himself about the new razor.
The man read the instructions while cautioning herself about the new razor.
The barber read the instructions while cautioning himself about the new razor.
The barber read the instructions while cautioning herself about the new razor.


## 55 BROKEN TOOLS
The handyman bought a new screwdriver after cautioning himself about the broken one.
The handyman bought a new screwdriver after cautioning herself about the broken one.
The carpenter bought a new screwdriver after cautioning himself about the broken one.
The carpenter bought a new screwdriver after cautioning herself about the broken one.


## 56 MODERNIZATION
The handyman worked faster after buying himself a new chain saw.
The handyman worked faster after buying herself a new chain saw.
The carpenter worked faster after buying himself a new chain saw.
The carpenter worked faster after buying herself a new chain saw.


## 57 RUMOURS
The Count decided to make further inquiries after upsetting himself about the rumours.
The Count decided to make further inquiries after upsetting herself about the rumours.
The Dean decided to make further inquiries after upsetting himself about the rumours.
The Dean decided to make further inquiries after upsetting herself about the rumours.


## 58 TILL DEATH DO US PART
The Count was determined to get a divorce after tormenting himself about the affair.
The Count was determined to get a divorce after tormenting herself about the affair.
The Dean was determined to get a divorce after tormenting himself about the affair.
The Dean was determined to get a divorce after tormenting herself about the affair.


## 59 A USED NEEDLE
The fisherman was very careful after pricking himself with a syringe needle.
The fisherman was very careful after pricking herself with a syringe needle.
The dentist was very careful after pricking himself with a syringe needle.
The dentist was very careful after pricking herself with a syringe needle.


## 60 A NEW BOAT
The fisherman saved every penny hoping to buy himself a new boat.
The fisherman saved every penny hoping to buy herself a new boat.
The dentist saved every penny hoping to buy himself a new boat.
The dentist saved every penny hoping to buy herself a new boat.


## 61 BAD NEWS
The postman delivered the telegram despite upsetting himself about the message.
The postman delivered the telegram despite upsetting herself about the message.
The soldier delivered the telegram despite upsetting himself about the message.
The soldier delivered the telegram despite upsetting herself about the message.


## 62 A GOOD LAUGH
The postman delivered the comic message while laughing at himself out loud.
The postman delivered the comic message while laughing at herself out loud.
The soldier delivered the comic message while laughing at himself out loud.
The soldier delivered the comic message while laughing at herself out loud.

## 63 FORGETFULNESS
The clergyman forgot the previous failure after praising himself for the successful concert.
The clergyman forgot the previous failure after praising herself for the successful concert.
The drummer forgot the previous failure after praising himself for the successful concert.
The drummer forgot the previous failure after praising herself for the successful concert.

## 64 THE CHARITY SHOW
The clergyman was convinced to participate after reminding himself about the charity money.
The clergyman was convinced to participate after reminding herself about the charity money.
The drummer was convinced to participate after reminding himself about the charity money.
The drummer was convinced to participate after reminding herself about the charity money.

## 65 NEW ALARM SYSTEM
The bellboy fixed the problem after familiarizing himself with the new system.
The bellboy fixed the problem after familiarizing herself with the new system.
The electrician fixed the problem after familiarizing himself with the new system.
The electrician fixed the problem after familiarizing herself with the new system.

## 66 THE BROKEN ELEVATOR
The bellboy preferred to take the stairs after cautioning himself about the elevator.
The bellboy preferred to take the stairs after cautioning herself about the elevator.
The electrician preferred to take the stairs after cautioning himself about the elevator.
The electrician preferred to take the stairs after cautioning herself about the elevator.

## 67 DEHYDRATION DANGER
The Englishman learnt about dehydration symptoms while preparing himself for the desert trip.
The Englishman learnt about dehydration symptoms while preparing herself for the desert trip.
The officer learnt about dehydration symptoms while preparing himself for the desert trip.
The officer learnt about dehydration symptoms while preparing herself for the desert trip.

## 68 COLD FEET
he Englishman decided to flee after imagining himself hurt in the battlefield.
The Englishman decided to flee after imagining herself hurt in the battlefield.
The officer decided to flee after imagining himself hurt in the battlefield.
The officer decided to flee after imagining herself hurt in the battlefield.

## 69 THE CHASE
The Duke decided to chase the deer after reassuring himself about the fast horse.
The Duke decided to chase the deer after reassuring herself about the fast horse.
The hunter decided to chase the deer after reassuring himself about the fast horse.
The hunter decided to chase the deer after reassuring herself about the fast horse.

## 70 FOX HUNTING
The Duke watched the fox silently after convincing himself not to shoot.
The Duke watched the fox silently after convincing herself not to shoot.
The hunter watched the fox silently after convincing himself not to shoot.
The hunter watched the fox silently after convincing herself not to shoot.

## 71 MOTORING DREAMS
The Lord decided to buy a Porsche after teaching himself about race cars.
The Lord decided to buy a Porsche after teaching herself about race cars.
The mechanic decided to buy a Porsche after teaching himself about race cars.
The mechanic decided to buy a Porsche after teaching herself about race cars.

## 72 IMPORTANT HANDBOOK
The Lord managed to fix the car after familiarizing himself with the handbook.
The Lord managed to fix the car after familiarizing herself with the handbook.
The mechanic managed to fix the car after familiarizing himself with the handbook.
The mechanic managed to fix the car after familiarizing herself with the handbook.

## 73 NEW JOB
The waiter left the ship after promising himself to find another job.
The waiter left the ship after promising herself to find another job.
The sailor left the ship after promising himself to find another job.
The sailor left the ship after promising herself to find another job.

## 74 NEVER AGAIN
The waiter fell in love after persuading himself this cannot happen again.
The waiter fell in love after persuading herself this cannot happen again.
The sailor fell in love after persuading himself this cannot happen again.
The sailor fell in love after persuading herself this cannot happen again.

## 75 HOT SPOT
The grandfather managed to turn the heating off after familiarizing himself with the remote control.
The grandfather managed to turn the heating off after familiarizing herself with the remote control.
The plumber managed to turn the heating off after familiarizing himself with the remote control.
The plumber managed to turn the heating off after familiarizing herself with the remote control.

## 76  AMNESIA
The grandfather succeeded in handling the leak after reminding himself where the pipes were.
The grandfather succeeded in handling the leak after reminding herself where the pipes were.
The plumber succeeded in handling the leak after reminding himself where the pipes were.
The plumber succeeded in handling the leak after reminding herself where the pipes were.

## 77 SECURITY IN SKY SCRAPERS
The watchman checked all the offices after reminding himself of the security regulations.
The watchman checked all the offices after reminding herself of the security regulations.
The guard checked all the offices after reminding himself of the security regulations.
The guard checked all the offices after reminding herself of the security regulations.

## 78 A TICKING BOMB
The watchman volunteered to neutralize the bomb despite putting himself on the line.
The watchman volunteered to neutralize the bomb despite putting herself on the line.
The guard volunteered to neutralize the bomb despite putting himself on the line.
The guard volunteered to neutralize the bomb despite putting herself on the line.

## 79 EFFICIENCY
The repairman fixed the broken window after letting himself into the empty office.
The repairman fixed the broken window after letting herself into the empty office.
The janitor fixed the broken window after letting himself into the empty office.
The janitor fixed the broken window after letting herself into the empty office.

## 80 NEW FIRE REGULATIONS
The repairman installed the smoke detector after reminding himself about the fire hazards.
The repairman installed the smoke detector after reminding herself about the fire hazards.
The janitor installed the smoke detector after reminding himself about the fire hazards.
The janitor installed the smoke detector after reminding herself about the fire hazards.

81 BABY FOOD
The spokeswoman answered questions concerning the food after familiarizing herself with the ingredients.
The spokeswoman answered questions concerning the food after familiarizing himself with the ingredients.
The nutritionist answered questions concerning the food after familiarizing herself with the ingredients.
The nutritionist answered questions concerning the food after familiarizing himself with the ingredients.

82 JUNK FOOD
The spokeswoman advocated the company's products after reminding herself of the promised raise.
The spokeswoman advocated the company's products after reminding himself of the promised raise.
The nutritionist advocated the company's products after reminding herself of the promised raise.
The nutritionist advocated the company's products after reminding himself of the promised raise.

83 GOING TO LONDON
The housemaid asked to leave earlier after reminding herself about the long journey.
The housemaid asked to leave earlier after reminding himself about the long journey.
The babysitter asked to leave earlier after reminding herself about the long journey.
The babysitter asked to leave earlier after reminding himself about the long journey.

84 THERE'S NOTHING LIKE A NICE CUP OF HOT CHOCOLATE
The housemaid decided to watch an old movie after preparing herself some hot chocolate.
The housemaid decided to watch an old movie after preparing himself some hot chocolate.
The babysitter decided to watch an old movie after preparing herself some hot chocolate.
The babysitter decided to watch an old movie after preparing himself some hot chocolate.

85 PAINFUL MEMORY
The princess fell in love again after letting herself forget the last affair.
The princess fell in love again after letting himself forget the last affair.
The manicurist fell in love again after letting herself forget the last affair.
The manicurist fell in love again after letting himself forget the last affair.

86 NEVER TOO LATE
The princess registered at the university after convincing herself that education was important.
The princess registered at the university after convincing himself that education was important.
The manicurist registered at the university after convincing herself that education was important.
The manicurist registered at the university after convincing himself that education was important.

87 THE NEW TUNES FOR THE SHOW
The chorus-girl believed the show would be a hit after reassuring herself about the hip-hop tunes.
The chorus-girl believed the show would be a hit after reassuring himself about the hip-hop tunes.
The stripper believed the show would be a hit after reassuring herself about the hip-hop tunes.
The stripper believed the show would be a hit after reassuring himself about the hip-hop tunes.

88 ENDLESS DEMANDS
The chorus-girl demanded a better role after praising herself in the newspaper.
The chorus-girl demanded a better role after praising himself in the newspaper.
The stripper demanded a better role after praising herself in the newspaper.
The stripper demanded a better role after praising himself in the newspaper.

## 89 CONVINCING EVIDENCE
The policewoman studied the documents carefully before convincing herself to investigate the case.
The policewoman studied the documents carefully before convincing himself to investigate the case.
The secretary studied the documents carefully before convincing herself to investigate the case.
The secretary studied the documents carefully before convincing himself to investigate the case.

## 90 TESTIMONY IN THE CRIMINAL COURT
The policewoman remembered all the details after preparing herself to testify in court.
The policewoman remembered all the details after preparing himself to testify in court.
The secretary remembered all the details after preparing herself to testify in court.
The secretary remembered all the details after preparing himself to testify in court.

## 91 A ROMANTIC STORY
The actress started writing a new book after persuading herself the story was popular.
The actress started writing a new book after persuading himself the story was popular.
The gymnast started writing a new book after persuading herself the story was popular.
The gymnast started writing a new book after persuading himself the story was popular.

## 92 HOLLYWOOD PARTIES
The actress was offered a role in the new film after introducing herself at the Hollywood party.
The actress was offered a role in the new film after introducing himself at the Hollywood party.
The gymnast was offered a role in the new film after introducing herself at the Hollywood party.
The gymnast was offered a role in the new film after introducing himself at the Hollywood party.

## 93 PROFESSIONAL RISKS
The showgirl adopted new training techniques after cautioning herself about the injury risk.
The showgirl adopted new training techniques after cautioning himself about the injury risk.
The dancer adopted new training techniques after cautioning herself about the injury risk.
The dancer adopted new training techniques after cautioning himself about the injury risk.

## 94 HARD WORK
The showgirl couldn't perform pirouettes before training herself for many weeks.
The showgirl couldn't perform pirouettes before training himself for many weeks.
The dancer couldn't perform pirouettes before training herself for many weeks.
The dancer couldn't perform pirouettes before training himself for many weeks.

## 95 THE WEDDING
The bridesmaid organised the flowers after familiarizing herself with some designs.
The bridesmaid organised the flowers after familiarizing himself with some designs.
The florist organised the flowers after familiarizing herself with some designs.
The florist organised the flowers after familiarizing himself with some designs.

## 96 THE FLOWER ARRANGEMENTS
The bridesmaid showed off with the pictures while praising herself for the beautiful flowers.
The bridesmaid showed off with the pictures while praising himself for the beautiful flowers.
The florist showed off with the pictures while praising herself for the beautiful flowers.
The florist showed off with the pictures while praising himself for the beautiful flowers.

## 97 DEVOTED SERVICE
The waitress brought cold water after reminding herself about the complaints.
The waitress brought cold water after reminding himself about the complaints.
The nurse brought cold water after reminding herself about the complaints.
The nurse brought cold water after reminding himself about the complaints.

98 UNEMPLOYMENT AND DEPRESSION
The waitress became depressed after finding herself unemployed again and again.
The waitress became depressed after finding himself unemployed again and again.
The nurse became depressed after finding herself unemployed again and again.
The nurse became depressed after finding himself unemployed again and again.

99 TRADITIONAL CHINESE RECIPE
The kitchenmaid prepared an excellent dish after familiarising herself with the Cantonese recipe.
The kitchenmaid prepared an excellent dish after familiarising himself with the Cantonese recipe.
The designer prepared an excellent dish after familiarising herself with the Cantonese recipe.
The designer prepared an excellent dish after familiarising himself with the Cantonese recipe.

100 HAZARDS IN THE KITCHEN
The kitchenmaid became more cautious after cutting herself with the sharp knife.
The kitchenmaid became more cautious after cutting himself with the sharp knife.
The designer became more cautious after cutting herself with the sharp knife.
The designer became more cautious after cutting himself with the sharp knife.

101 THE ARGUMENT
The maid decided to look for another job after reminding herself about the argument.
The maid decided to look for another job after reminding himself about the argument.
The housekeeper decided to look for another job after reminding herself about the argument.
The housekeeper decided to look for another job after reminding himself about the argument.

102 FANCY DREAMS
The maid cleaned the big windows while imagining herself sunbathing near the pool.
The maid cleaned the big windows while imagining himself sunbathing near the pool.
The housekeeper cleaned the big windows while imagining herself sunbathing near the pool.
The housekeeper cleaned the big windows while imagining himself sunbathing near the pool.

103 OBESSITY PROBLEMS
The mother preferred healthy food after reminding herself about being overweight.
The mother preferred healthy food after reminding himself about being overweight.
The dietician preferred healthy food after reminding herself about being overweight.
The dietician preferred healthy food after reminding himself about being overweight.

104 VEGGIES
The mother began cooking more vegetables after teaching herself about vegetarian food.
The mother began cooking more vegetables after teaching himself about vegetarian food.
The dietician began cooking more vegetables after teaching herself about vegetarian food.
The dietician began cooking more vegetables after teaching himself about vegetarian food.

105 LOST IN A GOOD BOOK
The governess just ignored the noise while enjoying herself with a good book.
The governess just ignored the noise while enjoying himself with a good book.
The caregiver just ignored the noise while enjoying herself with a good book.
The caregiver just ignored the noise while enjoying himself with a good book.

106 UNCOMFORTABLE SILENCE
The governess kept silent while asking herself what to do.
The governess kept silent while asking himself what to do.
The caregiver kept silent while asking herself what to do.
The caregiver kept silent while asking himself what to do.

107 THE PARTY AT THE MANSION
The baroness ignored the gossip while praising herself for the successful party.
The baroness ignored the gossip while praising himself for the successful party.
The socialite ignored the gossip while praising herself for the successful party.
The socialite ignored the gossip while praising himself for the successful party.

108 SUMMER VACATION
The baroness spent the summer out of town while giving herself a break from socializing.
The baroness spent the summer out of town while giving himself a break from socializing.
The socialite spent the summer out of town while giving herself a break from socializing.
The socialite spent the summer out of town while giving himself a break from socializing.

109 LEAVING
The niece left the country after promising herself to visit very soon.
The niece left the country after promising himself to visit very soon.
The hairdresser left the country after promising herself to visit very soon.
The hairdresser left the country after promising himself to visit very soon.

110 MIRROR MIRROR ON THE WALL
The niece was ready to meet the family after checking herself again in the mirror.
The niece was ready to meet the family after checking himself again in the mirror.
The hairdresser was ready to meet the family after checking herself again in the mirror.
The hairdresser was ready to meet the family after checking himself again in the mirror.

111 DANGEROUS SUN
 The mermaid never came back to the beach after cautioning herself about the danger.
The mermaid never came back to the beach after cautioning himself about the danger.
The sunbather never came back to the beach after cautioning herself about the danger.
The sunbather never came back to the beach after cautioning himself about the danger.

112 AT THE BEACH
The mermaid desperately looked for the ring after reminding herself about the enchanted rendezvous.
The mermaid desperately looked for the ring after reminding himself about the enchanted rendezvous.
The sunbather desperately looked for the ring after reminding herself about the enchanted rendezvous.
The sunbather desperately looked for the ring after reminding himself about the enchanted rendezvous.

113 THE CONCERT AT THE PARK
The schoolgirl went home early after hurting herself during the rock concert.
The schoolgirl went home early after hurting himself during the rock concert.
The groupie went home early after hurting herself during the rock concert.
The groupie went home early after hurting himself during the rock concert.

114 A MISSED OPPORTUNITY
The schoolgirl calmed down only after promising herself to see the next concert.
The schoolgirl calmed down only after promising himself to see the next concert.
The groupie calmed down only after promising herself to see the next concert.
The groupie calmed down only after promising himself to see the next concert.

115 SHORT MEMORY
The housewife easily forgot this incident despite criticizing herself about being offensive.
The housewife easily forgot this incident despite criticizing himself about being offensive.
The feminist easily forgot this incident despite criticizing herself about being offensive.
The feminist easily forgot this incident despite criticizing himself about being offensive.

## 116 DOMESTIC FRUSTERATION
The housewife was very frustrated after forcing herself to finish the cleaning.
The housewife was very frustrated after forcing himself to finish the cleaning.
The feminist was very frustrated after forcing herself to finish the cleaning.
The feminist was very frustrated after forcing himself to finish the cleaning.

## 117 FAMILY REUNION
The sister reluctantly entered the house after preparing herself for the family reunion.
The sister reluctantly entered the house after preparing himself for the family reunion.
The teenybopper reluctantly entered the house after preparing herself for the family reunion.
The teenybopper reluctantly entered the house after preparing himself for the family reunion.

## 118 BROKEN HEART
The sister couldn't wake up after crying herself to sleep last night.
The sister couldn't wake up after crying himself to sleep last night.
The teenybopper couldn't wake up after crying herself to sleep last night.
The teenybopper couldn't wake up after crying himself to sleep last night.

## 119 CONSOLATION
The widow became accustomed to the new situation after consoling herself about the loss.
The widow became accustomed to the new situation after consoling himself about the loss.
The librarian became accustomed to the new situation after consoling herself about the loss.
The librarian became accustomed to the new situation after consoling himself about the loss.

## 120 FEELING BETTER
The widow felt much better after losing herself in work last week.
The widow felt much better after losing himself in work last week.
The librarian felt much better after losing herself in work last week.
The librarian felt much better after losing himself in work last week.

## 121 FEELING COMFORTABLE
 The hostess felt more comfortable after introducing herself earlier that night.
The hostess felt more comfortable after introducing himself earlier that night.
The receptionist felt more comfortable after introducing herself earlier that night.
The receptionist felt more comfortable after introducing himself earlier that night.

## 122 SMOKING BREAK
The hostess came back in after lighting herself a cigarette outside.
The hostess came back in after lighting himself a cigarette outside.
The receptionist came back in after lighting herself a cigarette outside.
The receptionist came back in after lighting himself a cigarette outside.

## 123 LEARNING FROM EXPERIENCE
The nursemaid was very stern after reminding herself of the previous experience.
The nursemaid was very stern after reminding himself of the previous experience.
The speech-therapist was very stern after reminding herself of the previous experience.
The speech-therapist was very stern after reminding himself of the previous experience.


## 124 SUMMER VACATION
The nursemaid returned to work after enjoying herself on vacation abroad.
The nursemaid returned to work after enjoying himself on vacation abroad.
The speech-therapist returned to work enjoying herself on vacation abroad.
The speech-therapist returned to work enjoying himself on vacation abroad.

## 125 BREAKING UP
The girlfriend said it was all over after pouring herself another cup of tea.
The girlfriend said it was all over after pouring himself another cup of tea.
The childminder said it was all over after pouring herself another cup of tea.
The childminder said it was all over after pouring himself another cup of tea.

## 126 IMAGINATION
The girlfriend agreed to move in after imagining herself in a wedding dress.
The girlfriend agreed to move in after imagining himself in a wedding dress.
The childminder agreed to move in after imagining herself in a wedding dress.
The childminder agreed to move in after imagining himself in a wedding dress.

## 127 GOOD TIME
The duchess came back home after enjoying herself on a luxury boat trip.
The duchess came back home after enjoying himself on a luxury boat trip.
The model came back home after enjoying herself on a luxury boat trip.
The model came back home after enjoying himself on a luxury boat trip.

## 128 CLOTHING EXPENSES
The duchess was short of money after buying herself new clothes in London.
The duchess was short of money after buying himself new clothes in London.
The model was short of money after buying herself new clothes in London.
The model was short of money after buying himself new clothes in London.

## 129 LOOKING GOOD
The brunette gazed at the mirror while priding herself on the new look.
The brunette gazed at the mirror while priding himself on the new look.
The typist gazed at the mirror while priding herself on the new look.
The typist gazed at the mirror while priding himself on the new look.

## 130 TRENDY HAIRSTYLE
The brunette took a short haircut after convincing herself of the trendy hairstyle.
The brunette took a short haircut after convincing himself of the trendy hairstyle.
The typist took a short haircut after convincing herself of the trendy hairstyle.
The typist took a short haircut after convincing himself of the trendy hairstyle.

## 131 AT THE CARBOOT SALE
The dinner-lady sold handmade sweaters after finding herself unemployed for three months.
The dinner-lady sold handmade sweaters after finding himself unemployed for three months.
The knitter sold handmade sweaters after finding herself unemployed for three months.
The knitter sold handmade sweaters after finding himself unemployed for three months.

## 132 WARM SWEATERS
The dinner-lady prepared warm sweaters for the winter after reminding herself of last year's snow.
The dinner-lady prepared warm sweaters for the winter after reminding himself of last year's snow.
The knitter prepared warm sweaters for the winter after reminding herself of last year's snow.
The knitter prepared warm sweaters for the winter after reminding himself of last year's snow.

## 133 IN THE STORE
The daughter left the store after buying herself a new MP3 player.
The daughter left the store after buying himself a new MP3 player.
The shopper left the store after buying herself a new MP3 player.
The shopper left the store after buying himself a new MP3 player.

## 134 WELL SPENT MONEY
The daughter purchased a new car after promising herself to save the money.
The daughter purchased a new car after promising himself to save the money.
The shopper purchased a new car after promising herself to save the money.
The shopper purchased a new car after promising himself to save the money.

## 135 AT THE MATCH
The girl shouted very loud despite giving herself a sore throat.
The girl shouted very loud despite giving himself a sore throat.
The cheerleader shouted very loud despite giving herself a sore throat.
The cheerleader shouted very loud despite giving himself a sore throat.

## 136 EMABARASSEMENT
The girl became embarrassed after letting herself get carried away.
The girl became embarrassed after letting himself get carried away.
The cheerleader became embarrassed after letting herself get carried away.
The cheerleader became embarrassed after letting himself get carried away.

## 137 STRESSFUL PREPARATIONS
 The bride was very nervous while preparing herself for the wedding.
The bride was very nervous while preparing himself for the wedding.
The beautician was very nervous while preparing herself for the wedding.
The beautician was very nervous while preparing himself for the wedding.

## 138 DRAMA AT THE WEDDING
The bride finally ran away after tormenting herself about the decision.
The bride finally ran away after tormenting himself about the decision.
The beautician finally ran away after tormenting herself about the decision.
The beautician finally ran away after tormenting himself about the decision.

## 139 THE BALANCE
The barmaid checked the balance while writing herself a memo note.
The barmaid checked the balance while writing himself a memo note.
The cashier checked the balance while writing herself a memo note.
The cashier checked the balance while writing himself a memo note.

## 140 AT THE END OF THE DAY
The barmaid counted the cash while reminding herself to double-check the sums.
The barmaid counted the cash while reminding himself to double-check the sums.
The cashier counted the cash while reminding herself to double-check the sums.
The cashier counted the cash while reminding himself to double-check the sums.

## 141 VINTAGE CLOTHING
The lady opened a vintage clothing boutique after establishing herself in the fashion business.
The lady opened a vintage clothing boutique after establishing himself in the fashion business.
The weaver opened a vintage clothing boutique after establishing herself in the fashion business.
The weaver opened a vintage clothing boutique after establishing himself in the fashion business.

## 142 POPULARITY
The lady became very popular after introducing herself at the designers' exhibition.
The lady became very popular after introducing himself at the designers' exhibition.
The weaver became very popular after introducing herself at the designers' exhibition.
The weaver became very popular after introducing himself at the designers' exhibition.

## 143 MILLION POUNDS

The heiress got the million pounds only after presenting herself at the lawyer's office.
The heiress got the million pounds only after presenting himself at the lawyer's office.
The cleaner got the million pounds only after presenting herself at the lawyer's office.
The cleaner got the million pounds only after presenting himself at the lawyer's office.

## 144 THE WILL

The heiress used the inheritance money only after reassuring herself the will was legal.
The heiress used the inheritance money only after reassuring himself the will was legal.
The cleaner used the inheritance money only after reassuring herself the will was legal.
The cleaner used the inheritance money only after reassuring himself the will was legal.

## 145 SMOKING BREAK

The nanny ignored the noise in the children's room when allowing herself a short break.
The nanny ignored the noise in the children's room when allowing himself a short break.
The single-parent ignored the noise in the children's room when allowing herself a short break.
The single-parent ignored the noise in the children's room when allowing himself a short break.

## 146 NEW JOB

The nanny was much better off after finding herself a job in Edinburgh.
The nanny was much better off after finding himself a job in Edinburgh.
The single-parent was much better off after finding herself a job in Edinburgh.
The single-parent was much better off after finding himself a job in Edinburgh.

## 147 SUICIDE

The stewardess wrote a suicide letter before killing herself with an overdose.
The stewardess wrote a suicide letter before killing himself with an overdose.
The prostitute wrote a suicide letter before killing herself with an overdose.
The prostitute wrote a suicide letter before killing himself with an overdose.

## 148 ACCIDENT

The stewardess was bleeding heavily after cutting herself with a table knife.
The stewardess was bleeding heavily after cutting himself with a table knife.
The prostitute was bleeding heavily after cutting herself with a table knife.
The prostitute was bleeding heavily after cutting himself with a table knife.

## 149 SATISFACTION

The aunt seemed very satisfied when praising herself for organising the party.
The aunt seemed very satisfied when praising himself for organising the party.
The teacher seemed very satisfied when praising herself for organising the party.
The teacher seemed very satisfied when praising himself for organising the party.

## 150 RELAXING

The aunt slowly relaxed after making herself a cup of tea.
The aunt slowly relaxed after making himself a cup of tea.
The teacher slowly relaxed after making herself a cup of tea.
The teacher slowly relaxed after making himself a cup of tea.

## 151 PROFICIENCY

The midwife had a lot of work after establishing herself as highly professional.
The midwife had a lot of work after establishing himself as highly professional.
The hygienist had a lot of work after establishing herself as highly professional.
The hygienist had a lot of work after establishing himself as highly professional.

152 RESPONSIBILITY
The midwife left the room only after convincing herself that everything was ok.
The midwife left the room only after convincing himself that everything was ok.
The hygienist left the room only after convincing herself that everything was ok.
The hygienist left the room only after convincing himself that everything was ok.

153 PREPARING FOR A LONG DAY IN COURT
The woman got dressed while preparing herself for the long day.
The woman got dressed while preparing himself for the long day.
The assistant got dressed while preparing herself for the long day.
The assistant got dressed while preparing himself for the long day.

154 EDUCATION
The woman got a good job after putting herself through night school.
The woman got a good job after putting himself through night school.
The assistant got a good job after putting herself through night school.
The assistant got a good job after putting himself through night school.

155 PSYCHOLOGICAL COUNSELLING
The wife prepared for the counselling meeting while promising herself to improve the communication.
The wife prepared for the counselling meeting while promising himself to improve the communication.
The therapist prepared for the counselling meeting while promising herself to improve the communication.
The therapist prepared for the counselling meeting while promising himself to improve the communication.

156 AFTER THE ACCIDENT
The wife tried to be helpful while reminding herself not to be emotional.
The wife tried to be helpful while reminding himself not to be emotional.
The therapist tried to be helpful while reminding herself not to be emotional.
The therapist tried to be helpful while reminding himself not to be emotional.

157 PREDICTIONS
The saleswoman predicted success only after convincing herself about the current situation.
The saleswoman predicted success only after convincing himself about the current situation.
The fortune-teller predicted success only after convincing herself about the current situation.
The fortune-teller predicted success only after convincing himself about the current situation.

158 DAY DREAMING
The saleswoman resumed talking after losing herself in thought for a minute.
The saleswoman resumed talking after losing himself in thought for a minute.
The fortune-teller resumed talking after losing herself in thought for a minute.
The fortune-teller resumed talking after losing himself in thought for a minute.

159 FASHION
The grandmother was wearing an old fashioned hat while priding herself for being so fashionable.
The grandmother was wearing an old fashioned hat while priding himself for being so fashionable.
The dressmaker was wearing an old fashioned hat while priding herself for being so fashionable.
The dressmaker was wearing an old fashioned hat while priding himself for being so fashionable.

160 GOLDEN AGE
The grandmother reluctantly consented to retire after promising herself to travel around the world.
The grandmother reluctantly consented to retire after promising himself to travel around the world.
The dressmaker reluctantly consented to retire after promising herself to travel around the world.
The dressmaker reluctantly consented to retire after promising himself to travel around the world.


## B.2 Experimental Items Cataphora


1 THE SHOT
After reassuring himself about the gun the marksman immediately aimed at the target.
After reassuring herself about the gun the marksman immediately aimed at the target.
After reassuring himself about the gun the murderer immediately aimed at the target.
After reassuring herself about the gun the murderer immediately aimed at the target.

2 HOMOCIDE
After cleaning himself from the blood the marksman quietly left the building.
After cleaning herself from the blood the marksman quietly left the building.
After cleaning himself from the blood the murderer quietly left the building.
After cleaning herself from the blood the murderer quietly left the building.

3 LOVE AFFAIR
After convincing himself about the romantic affair the cowboy moved to Australia.
After convincing herself about the romantic affair the cowboy moved to Australia.
After convincing himself about the romantic affair the farmer moved to Australia.
After convincing herself about the romantic affair the farmer moved to Australia.

4 WEATHER FORECAST
After reminding himself about the weather forecast the cowboy gathered the herd.
After reminding herself about the weather forecast the cowboy gathered the herd.
After reminding himself about the weather forecast the farmer gathered the herd.
After reminding herself about the weather forecast the farmer gathered the herd.

5 THE FIGHT
While tormenting himself over the fight the barman cleared the atmosphere.
While tormenting herself over the fight the barman cleared the atmosphere.
While tormenting himself over the fight the jailer cleared the atmosphere.
While tormenting herself over the fight the jailer cleared the atmosphere.

6 DRINKING PROBLEM
While promising himself not to drink on duty the barman prepared another drink.
While promising herself not to drink on duty the barman prepared another drink.
While promising himself not to drink on duty the jailer prepared another drink.
While promising herself not to drink on duty the jailer prepared another drink.

7 UNEXPECTED FINDINGS
While convincing himself about the findings the foreman considered alternative explanations.
While convincing herself about the findings the foreman considered alternative explanations.
While convincing himself about the findings the explorer considered alternative explanations.
While convincing herself about the findings the explorer considered alternative explanations.

8 PAINFUL DECISION
After familiarising himself with the report the foreman decided to suspend the project.
After familiarising herself with the report the foreman decided to suspend the project.
After familiarising himself with the report the explorer decided to suspend the project.
After familiarising herself with the report the explorer decided to suspend the project.

## 9 SUSPICIONS
After reminding himself about the suspicious questions the policeman investigated the story again.
After reminding herself about the suspicious questions the policeman investigated the story again.
After reminding himself about the suspicious questions the constable investigated the story again.
After reminding herself about the suspicious questions the constable investigated the story again.

## 10 DRUG DEAL
After convincing himself about the drug deal the policeman entered the building.
After convincing herself about the drug deal the policeman entered the building.
After convincing himself about the drug deal the constable entered the building.
After convincing herself about the drug deal the constable entered the building.

## 11 FIRE IN THE BUILDING
After pulling himself out of the danger the fireman was restless for hours.
After pulling herself out of the danger the fireman was restless for hours.
After pulling himself out of the danger the firefighter was restless for hours.
After pulling herself out of the danger the firefighter was restless for hours.

## 12 THE CAT
After reminding himself about the little cat the fireman climbed to the roof.
After reminding herself about the little cat the fireman climbed to the roof
After reminding himself about the little cat the firefighter climbed to the roof.
After reminding herself about the little cat the firefighter climbed to the roof.

## 13 ON THE HIJACKED PLANE
While putting himself on the line the spokesman carefully moved the bomb.
While putting herself on the line the spokesman carefully moved the bomb.
While putting himself on the line the pilot carefully moved the bomb.
While putting herself on the line the pilot carefully moved the bomb.

## 14 NEW REGULATIONS
After reminding himself the new regulations the spokesman explained the security procedures.
After reminding herself the new regulations the spokesman explained the security procedures.
After reminding himself the new regulations the pilot explained the security procedures.
After reminding herself the new regulations the pilot explained the security procedures.

## 15 AN IMPORTANT LETTER
After reminding himself about the letter the businessman went to the meeting.
After reminding herself about the letter the businessman went to the meeting.
After reminding himself about the letter the minister went to the meeting.
After reminding herself about the letter the minister went to the meeting.

## 16 TAX INVESTIGATION
While preparing himself for the tax inquiry the businessman drank a cup of coffee.
While preparing herself for the tax inquiry the businessman drank a cup of coffee.
While preparing himself for the tax inquiry the minister drank a cup of coffee.
While preparing herself for the tax inquiry the minister drank a cup of coffee.

## 17 A MORNING IN TOWN
After familiarising himself with the directions the gentleman found the new shop.
After familiarising herself with the directions the gentleman found the new shop.
After familiarising himself with the directions the driver found the new shop.
After familiarising herself with the directions the driver found the new shop.

18 THE ACCIDENT
After hurting himself in a car accident the gentleman asked for medical assistance.
After hurting herself in a car accident the gentleman asked for medical assistance.
After hurting himself in a car accident the driver asked for medical assistance.
After hurting herself in a car accident the driver asked for medical assistance.


19 BUISNESS COMPETITION
After working himself into frenzy yesterday the salesman became ill this morning.
After working herself into frenzy yesterday the salesman became ill this morning.
After working himself into frenzy yesterday the tailor became ill this morning.
After working herself into frenzy yesterday the tailor became ill this morning.

20 DEMAND FOR MORE MONEY
After arming himself with the formal letter the salesman demanded more money.
After arming herself with the formal letter the salesman demanded more money.
After arming himself with the formal letter the tailor demanded more money.
After arming herself with the formal letter the tailor demanded more money.

21 REGULATIONS
After reminding himself about the regulations the chairman performed the necessary procedures.
After reminding herself about the regulations the chairman performed the necessary procedures.
After reminding himself about the regulations the surgeon performed the necessary procedures.
After reminding herself about the regulations the surgeon performed the necessary procedures.

22 NEW MEDICINE
After reassuring himself about the side effects the chairman recommended the new medicine.
After reassuring herself about the side effects the chairman recommended the new medicine.
After reassuring himself about the side effects the surgeon recommended the new medicine.
After reassuring herself about the side effects the surgeon recommended the new medicine.

23 ON EASTER
After enjoying himself so much at Christmas the uncle came again at Easter.
After enjoying herself so much at Christmas the uncle came again at Easter.
After enjoying himself so much at Christmas the scout came again at Easter.
After enjoying herself so much at Christmas the scout came again at Easter.

24 CAMPING NIGHTMARE
After tormenting himself in the tent the uncle went to sleep in the car.
After tormenting herself in the tent the uncle went to sleep in the car.
After tormenting himself in the tent the scout went to sleep in the car.
After tormenting herself in the tent the scout went to sleep in the car.


25 THE PARTY
After reminding himself about last year's party the bachelor gladly promised to come.
After reminding herself about last year's party the bachelor gladly promised to come.
After reminding himself about last year's party the clown gladly promised to come.
After reminding herself about last year's party the clown gladly promised to come.

26 A SUCCESSFUL SHOW
After reminding himself of last year's success the bachelor agreed to participate in the show.
After reminding herself of last year's success the bachelor agreed to participate in the show.
After reminding himself of last year's success the clown agreed to participate in the show.
After reminding herself of last year's success the clown agreed to participate in the show.

## 27 BUSINESS TRIPS
After upsetting himself about the long separation the father often bought many presents.
After upsetting herself about the long separation the father often bought many presents.
After upsetting himself about the long separation the inventor often bought many presents.
After upsetting herself about the long separation the inventor often bought many presents.


## 28 BRILLIANT SOLUTIONS
After reassuring himself about finding a solution the father had brilliant ideas.
After reassuring herself about finding a solution the father had brilliant ideas.
After reassuring himself about finding a solution the inventor had brilliant ideas.
After reassuring herself about finding a solution the inventor had brilliant ideas.

## 29 DISAPPOINTMENT
After injuring himself during the training the sportsman couldn't take part in the match.
After injuring herself during the training the sportsman couldn't take part in the match.
After injuring himself during the training the footballer couldn't take part in the match.
After injuring herself during the training the footballer couldn't take part in the match.

## 30 MOTIVATION
After promising himself to break the record the sportsman was highly motivated.
After promising herself to break the record the sportsman was highly motivated.
After promising himself to break the record the footballer was highly motivated.
After promising herself to break the record the footballer was highly motivated.

## 31 SHOOTING IN AFRICA
After convincing himself about the publication the cameraman accepted the offer.
After convincing herself about the publication the cameraman accepted the offer.
After convincing himself about the publication the photographer accepted the offer.
After convincing herself about the publication the photographer accepted the offer.

## 32 FASHION SHOW IN AUSTRALIA
After reminding himself about the wonderful beaches the cameraman agreed to the location.
After reminding herself about the wonderful beaches the cameraman agreed to the location.
After reminding himself about the wonderful beaches the photographer agreed to the location.
After reminding herself about the wonderful beaches the photographer agreed to the location.

## 33 FAMILY MEETINGS
After reminding himself about the warm family meeting the nephew decided to come.
After reminding herself about the warm family meeting the nephew decided to come.
After reminding himself about the warm family meeting the General decided to come.
After reminding herself about the warm family meeting the General decided to come.


## 34 HOME SWEET HOME
After convincing himself to return home the nephew decided to leave the army.
After convincing herself to return home the nephew decided to leave the army.
After convincing himself to return home the General decided to leave the army.
After convincing herself to return home the General decided to leave the army.

## 35 COURT ORDER
After reminding himself about the court order the stepfather never came near the house again.
After reminding herself about the court order the stepfather never came near the house again.
After reminding himself about the court order the killer never came near the house again.
After reminding herself about the court order the killer never came near the house again.

## 36 IN THE LOCAL PUB
After injuring himself in the local pub the stepfather was immediately arrested.
After injuring herself in the local pub the stepfather was immediately arrested.
After injuring himself in the local pub the killer was immediately arrested.
After injuring herself in the local pub the killer was immediately arrested.


## 37 BROKEN GLASS
After cutting himself with broken glass the schoolboy was much more careful.
After cutting herself with broken glass the schoolboy was much more careful.
After cutting himself with broken glass the magician was much more careful.
After cutting herself with broken glass the magician was much more careful.

## 38 MAGIC CARDS
After teaching himself some new card tricks the schoolboy gave a wonderful show.
After teaching herself some new card tricks the schoolboy gave a wonderful show.
After teaching himself some new card tricks the magician gave a wonderful show.
After teaching herself some new card tricks the magician gave a wonderful show.

## 39 CRISIS AT WORK
While pouring himself a glass of Whisky the husband thought of the crisis.
While pouring herself a glass of Whisky the husband thought of the crisis.
While pouring himself a glass of Whisky the director thought of the crisis.
While pouring herself a glass of Whisky the director thought of the crisis.

## 40 A DREAM COMES TRUE
After promising himself to buy a yacht the husband decided to retire.
After promising herself to buy a yacht the husband decided to retire.
After promising himself to buy a yacht the director decided to retire.
After promising herself to buy a yacht the director decided to retire.

## 41 LOVE AND CHOCOLATES
After deluding himself about the love affair the boyfriend sent chocolates.
After deluding herself about the love affair the boyfriend sent chocolates.
After deluding himself about the love affair the trucker sent chocolates.
After deluding herself about the love affair the trucker sent chocolates.

## 42 TRUE LOVE
After convincing himself about being in love the boyfriend sent a sentimental letter.
After convincing herself about being in love the boyfriend sent a sentimental letter.
After convincing himself about being in love the trucker sent a sentimental letter.
After convincing herself about being in love the trucker sent a sentimental letter.


## 43 AN ACCIDENT IN THE WOODS
After injuring himself with an axe the son desperately wanted to go home.
After injuring herself with an axe the son desperately wanted to go home.
After injuring himself with an axe the logger desperately wanted to go home.
After injuring herself with an axe the logger desperately wanted to go home.

## 44 PROTECTING THE ROBIN
After reminding himself about the robins nest the son was reluctant to cut the tree.
After reminding herself about the robins nest the son was reluctant to cut the tree.
After reminding himself about the robins nest the logger was reluctant to cut the tree.
After reminding herself about the robins nest the logger was reluctant to cut the tree.

## 45 POVERTY AND COMPASSION
After reminding himself of the circumstances the landlord didn't raise the rental fee.
After reminding herself of the circumstances the landlord didn't raise the rental fee.
After reminding himself of the circumstances the executive didn't raise the rental fee.
After reminding herself of the circumstances the executive didn't raise the rental fee.

## 46 REFURBISHMENTS
After convincing himself about the low costs the landlord refurbished the apartments.
After convincing herself about the low costs the landlord refurbished the apartments.
After convincing himself about the low costs the executive refurbished the apartments.
After convincing herself about the low costs the executive refurbished the apartments.

## 47 IN THE NEIGHBOURHOOD
After finding himself out of job the milkman left the neighbourhood.
After finding herself out of job the milkman left the neighbourhood.
After finding himself out of job the butcher left the neighbourhood.
After finding herself out of job the butcher left the neighbourhood.

## 48 CLOSING THE BUSINESS
After reminding himself of the low profits the milkman decided to close down.
After reminding herself of the low profits the milkman decided to close down.
After reminding himself of the low profits the butcher decided to close down.
After reminding herself of the low profits the butcher decided to close down.

## 49 THE NEW PROJECT
After persuading himself about the project the congressman supported all actions.
After persuading herself about the project the congressman supported all actions.
After persuading himself about the project the senator supported all actions.
After persuading herself about the project the senator supported all actions.

## 50 DAMAGE CONTROL
After picturing to himself the potential consequences the congressman tried to prevent the publication.
After picturing to herself the potential consequences the congressman tried to prevent the publication.
After picturing to himself the potential consequences the senator tried to prevent the publication.
After picturing to herself the potential consequences the senator tried to prevent the publication.

## 51 FAMILY BUSINESS
After convincing himself to open a restaurant the brother left the family business.
After convincing herself to open a restaurant the brother left the family business.
After convincing himself to open a restaurant the chef left the family business.
After convincing herself to open a restaurant the chef left the family business.

## 52 COOKING SKILLS
After praising himself arrogantly for years the brother cooked a dreadful meal.
After praising herself arrogantly for years the brother cooked a dreadful meal.
After praising himself arrogantly for years the chef cooked a dreadful meal.
After praising herself arrogantly for years the chef cooked a dreadful meal.

## 53 HAZARDOUS TOOLS
After hurting himself with the rusty scissors the man carefully checked the other instrument.
After hurting herself with the rusty scissors the man carefully checked the other instrument.
After hurting himself with the rusty scissors the barber carefully checked the other instrument.
After hurting herself with the rusty scissors the barber carefully checked the other instrument.

## 54 NEW ELECTRIC RAZOR
After cautioning himself about the new razor the man read the instructions.
After cautioning herself about the new razor the man read the instructions.
After cautioning himself about the new razor the barber read the instructions.
After cautioning herself about the new razor the barber read the instructions.

## 55 BROKEN TOOLS
After cautioning himself about broken tools the handyman bought a new screwdriver.
After cautioning herself about broken tools the handyman bought a new screwdriver.
After cautioning himself about broken tools the carpenter bought a new screwdriver.
After cautioning herself about broken tools the carpenter bought a new screwdriver.

## 56 MODERNIZATION
After buying himself a new chain saw the handyman worked much faster.
After buying herself a new chain saw the handyman worked much faster.
After buying himself a new chain saw the carpenter worked much faster.
After buying herself a new chain saw the carpenter worked much faster.

## 57 RUMOURS
After upsetting himself about the rumours the Count secretly made further inquiries.
After upsetting herself about the rumours the Count secretly made further inquiries.
After upsetting himself about the rumours the Dean secretly made further inquiries.
After upsetting herself about the rumours the Dean secretly made further inquiries.

## 58 TILL DEATH DO US PART
After tormenting himself about the affair the Count was determined to get a divorce.
After tormenting herself about the affair the Count was determined to get a divorce.
After tormenting himself about the affair the Dean was determined to get a divorce.
After tormenting herself about the affair the Dean was determined to get a divorce.

## 59 A USED NEEDLE
After pricking himself with a syringe needle the fisherman was always very careful.
After pricking herself with a syringe needle the fisherman was always very careful.
After pricking himself with a syringe needle the dentist was always very careful.
After pricking herself with a syringe needle the dentist was always very careful.

## 60 A NEW BOAT
Hoping to buy himself a new boat the fisherman saved every penny.
Hoping to buy herself a new boat the fisherman saved every penny.
Hoping to buy himself a new boat the dentist saved every penny.
Hoping to buy herself a new boat the dentist saved every penny.

## 61 BAD NEWS
While upsetting himself about the message the postman reluctantly delivered the telegram.
While upsetting herself about the message the postman reluctantly delivered the telegram.
While upsetting himself about the message the soldier reluctantly delivered the telegram.
While upsetting herself about the message the soldier reluctantly delivered the telegram.

## 62 A GOOD LAUGH
While laughing at himself out loud the postman delivered the comic message.
While laughing at herself out loud the postman delivered the comic message.
While laughing at himself out loud the soldier delivered the comic message.
While laughing at herself out loud the soldier delivered the comic message.

## 63 FORGETFULNESS
After praising himself for the successful concert the clergyman forgot the previous failure.
After praising herself for the successful concert the clergyman forgot the previous failure.
After praising himself for the successful concert the drummer forgot the previous failure.
After praising herself for the successful concert the drummer forgot the previous failure.

## 64 THE CHARITY SHOW
After reminding himself about the charity money the clergyman was convinced to participate.
After reminding herself about the charity money the clergyman was convinced to participate.
After reminding himself about the charity money the drummer was convinced to participate.
After reminding herself about the charity money the drummer was convinced to participate.

## 65 NEW ALARM SYSTEM
After familiarising himself with the new system the bellboy easily fixed the problem.
After familiarising herself with the new system the bellboy easily fixed the problem.
After familiarising himself with the new system the electrician easily fixed the problem.
After familiarising herself with the new system the electrician easily fixed the problem.

## 66 THE BROKEN ELEVATOR
After cautioning himself about the elevator the bellboy preferred to take the stairs.
After cautioning herself about the elevator the bellboy preferred to take the stairs.
After cautioning himself about the elevator the electrician preferred to take the stairs.
After cautioning herself about the elevator the electrician preferred to take the stairs.

## 67 DEHYDRATION DANGER
While preparing himself for the desert trip the Englishman learnt about dehydration symptoms.
While preparing herself for the desert trip the Englishman learnt about dehydration symptoms.
While preparing himself for the desert trip the officer learnt about dehydration symptoms.
While preparing herself for the desert trip the officer learnt about dehydration symptoms.

## 68 COLD FEET
After imagining himself hurt in the battlefield the Englishman decided to flee.
After imagining herself hurt in the battlefield the Englishman decided to flee.
After imagining himself hurt in the battlefield the officer decided to flee.
After imagining herself hurt in the battlefield the officer decided to flee.

## 69 THE CHASE
After reassuring himself about the fast horse the Duke decided to chase the deer.
After reassuring herself about the fast horse the Duke decided to chase the deer.
After reassuring himself about the fast horse the hunter decided to chase the deer.
After reassuring herself about the fast horse the hunter decided to chase the deer.

## 70 FOX HUNTING
After convincing himself not to shoot the Duke watched the fox silently.
After convincing herself not to shoot the Duke watched the fox silently.
After convincing himself not to shoot the hunter watched the fox silently.
After convincing herself not to shoot the hunter watched the fox silently.

## 71 MOTORING DREAMS
After teaching himself about race cars the Lord decided to buy a Porsche.
After teaching herself about race cars the Lord decided to buy a Porsche.
After teaching himself about race cars the mechanic decided to buy a Porsche.
After teaching herself about race cars the mechanic decided to buy a Porsche.

## 72 IMPORTANT HANDBOOK
After familiarizing himself with the handbook the Lord managed to fix the car.
After familiarizing herself with the handbook the Lord managed to fix the car.
After familiarizing himself with the handbook the mechanic managed to fix the car.
After familiarizing herself with the handbook the mechanic managed to fix the car.

## 73 NEW JOB
After promising himself to find another job the waiter left the ship.
After promising herself to find another job the waiter left the ship.
After promising himself to find another job the sailor left the ship.
After promising herself to find another job the sailor left the ship.

## 74 NEVER AGAIN
After persuading himself this cannot happen again the waiter fell in love.
After persuading herself this cannot happen again the waiter fell in love.
After persuading himself this cannot happen again the sailor fell in love.
After persuading herself this cannot happen again the sailor fell in love.

## 75 HOT SPOT
After familiarizing himself with the remote control the grandfather turned the heating off.
After familiarizing herself with the remote control the grandfather turned the heating off.
After familiarizing himself with the remote control the plumber turned the heating off.
After familiarizing herself with the remote control the plumber turned the heating off.

## 76 AMNESIA
After reminding himself where the pipes were the grandfather succeeded in handling the leak.
After reminding herself where the pipes were the grandfather succeeded in handling the leak.
After reminding himself where the pipes were the plumber succeeded in handling the leak.
After reminding herself where the pipes were the plumber succeeded in handling the leak.

## 77 SECURITY IN SKY SCRAPERS
After reminding himself of the security regulations the watchman checked all the offices.
After reminding herself of the security regulations the watchman checked all the offices.
After reminding himself of the security regulations the guard checked all the offices.
After reminding herself of the security regulations the guard checked all the offices.

## 78 A TICKING BOMB
Despite putting himself on the line the watchman volunteered to neutralize the bomb.
Despite putting herself on the line the watchman volunteered to neutralize the bomb.
Despite putting himself on the line the guard volunteered to neutralize the bomb.
Despite putting herself on the line the guard volunteered to neutralize the bomb.

## 79 EFFICIENCY
After letting himself into the empty office the repairman fixed the broken window.
After letting herself into the empty office the repairman fixed the broken window.
After letting himself into the empty office the janitor fixed the broken window.
After letting herself into the empty office the janitor fixed the broken window.

## 80 NEW FIRE REGULATIONS
After reminding himself about the fire hazards the repairman installed the smoke detector.
After reminding herself about the fire hazards the repairman installed the smoke detector.
After reminding himself about the fire hazards the janitor installed the smoke detector.
After reminding herself about the fire hazards the janitor installed the smoke detector.

## 81 BABY FOOD
After familiarising herself with the ingredients the spokeswoman answered questions concerning the food.
After familiarising himself with the ingredients the spokeswoman answered questions concerning the food.
After familiarising herself with the ingredients the nutritionist answered questions concerning the food.
After familiarising himself with the ingredients the nutritionist answered questions concerning the food.

## 82 JUNK FOOD
After reminding herself of the promised raise the spokeswoman advocated the company's products.
After reminding himself of the promised raise the spokeswoman advocated the company's products.
After reminding herself of the promised raise the nutritionist advocated the company's products.
After reminding himself of the promised raise the nutritionist advocated the company's products.


## 83 GOING TO LONDON
After reminding herself about the long journey the housemaid asked to leave earlier.
After reminding himself about the long journey the housemaid asked to leave earlier.
After reminding herself about the long journey the babysitter asked to leave earlier.
After reminding himself about the long journey the babysitter asked to leave earlier.

## 84 THERE'S NOTHING LIKE A NICE CUP OF HOT CHOCOLATE
After preparing herself some hot chocolate the housemaid watched an old TV movie.
After preparing himself some hot chocolate the housemaid watched an old TV movie.
After preparing herself some hot chocolate the babysitter watched an old TV movie.
After preparing himself some hot chocolate the babysitter watched an old TV movie.

## 85 PAINFUL MEMORY
After letting herself forget the last affair the princess fell in love again.
After letting himself forget the last affair the princess fell in love again.
After letting herself forget the last affair the manicurist fell in love again.
After letting himself forget the last affair the manicurist fell in love again.

## 86 NEVER TOO LATE
After convincing herself that education was important the princess registered at the university.
After convincing himself that education was important the princess registered at the university.
After convincing herself that education was important the manicurist registered at the university.
After convincing himself that education was important the manicurist registered at the university.

## 87 THE NEW TUNES FOR THE SHOW
After reassuring herself about the hip-hop tunes the chorus-girl believed the show would be successful.
After reassuring himself about the hip-hop tunes the chorus-girl believed the show would be successful.
After reassuring herself about the hip-hop tunes the stripper believed the show would be successful.
After reassuring himself about the hip-hop tunes the stripper believed the show would be successful.

## 88 ENDLESS DEMANDS
After praising herself in the newspaper the chorus-girl demanded a better role.
After praising himself in the newspaper the chorus-girl demanded a better role.
After praising herself in the newspaper the stripper demanded a better role.
After praising himself in the newspaper the stripper demanded a better role.

## 89 CONVINCING EVIDENCE
Before convincing herself to investigate the case the policewoman studied the documents carefully.
Before convincing himself to investigate the case the policewoman studied the documents carefully.
Before convincing herself to investigate the case the secretary studied the documents carefully.
Before convincing himself to investigate the case the secretary studied the documents carefully.

## 90 TESTIMONY IN THE CRIMINAL COURT
After preparing herself to testify in court the policewoman remembered all the details.
After preparing himself to testify in court the policewoman remembered all the details.
After preparing herself to testify in court the secretary remembered all the details.
After preparing himself to testify in court the secretary remembered all the details.

## 91 A ROMANTIC STORY
After persuading herself the story was popular the actress started writing a new book.
After persuading himself the story was popular the actress started writing a new book.
After persuading herself the story was popular the gymnast started writing a new book.
After persuading himself the story was popular the gymnast started writing a new book.

## 92 HOLLYWOOD PARTIES
After introducing herself at the Hollywood party the actress got the role in that film.
After introducing himself at the Hollywood party the actress got the role in that film.
After introducing herself at the Hollywood party the gymnast got the role in that film.
After introducing himself at the Hollywood party the gymnast got the role in that film.

## 93 PROFESSIONAL RISKS
After cautioning herself about the injury risk the showgirl adopted new training techniques.
After cautioning himself about the injury risk the showgirl adopted new training techniques.
After cautioning herself about the injury risk the dancer adopted new training techniques.
After cautioning himself about the injury risk the dancer adopted new training techniques.

## 94 HARD WORK
Before training herself for many weeks the showgirl couldn't perform pirouettes.
Before training himself for many weeks the showgirl couldn't perform pirouettes.
Before training herself for many weeks the dancer couldn't perform pirouettes.
Before training himself for many weeks the dancer couldn't perform pirouettes.

## 95 THE WEDDING
After familiarizing herself with some designs the bridesmaid arranged the flowers for the ceremony.
After familiarizing himself with some designs the bridesmaid arranged the flowers for the ceremony.
After familiarizing herself with some designs the florist arranged the flowers for the ceremony.
After familiarizing himself with some designs the florist arranged the flowers for the ceremony.

## 96 THE FLOWER ARRANGEMENTS
While praising herself for the beautiful flowers the bridesmaid showed off with the pictures.
While praising himself for the beautiful flowers the bridesmaid showed off with the pictures.
While praising herself for the beautiful flowers the florist showed off with the pictures.
While praising himself for the beautiful flowers the florist showed off with the pictures.

## 97 DEVOTED SERVICE
After reminding herself about the complaints the waitress brought cold water.
After reminding himself about the complaints the waitress brought cold water.
After reminding herself about the complaints the nurse brought cold water.
After reminding himself about the complaints the nurse brought cold water.

## 98 UNEMPLOYMENT AND DEPRESSION
After finding herself unemployed again and again the waitress became depressed.
After finding himself unemployed again and again the waitress became depressed.
After finding herself unemployed again and again the nurse became depressed.
After finding himself unemployed again and again the nurse became depressed.

## 99 TRADITIONAL CHINESE RECIPE
After familiarizing herself with the Cantonese recipe the kitchenmaid prepared an excellent Chinese dish.
After familiarizing himself with the Cantonese recipe the kitchenmaid prepared an excellent Chinese dish.
After familiarizing herself with the Cantonese recipe the designer prepared an excellent Chinese dish.
After familiarizing himself with the Cantonese recipe the designer prepared an excellent Chinese dish.

## 100 HAZARDS IN THE KITCHEN
After cutting herself with the sharp knife the kitchenmaid became more cautious.
After cutting himself with the sharp knife the kitchenmaid became more cautious.
After cutting herself with the sharp knife the designer became more cautious.
After cutting himself with the sharp knife the designer became more cautious.

## 101 THE ARGUMENT
After reminding herself about the argument the maid decided to look for another job.
After reminding himself about the argument the maid decided to look for another job.
After reminding herself about the argument the housekeeper decided to look for another job.
After reminding himself about the argument the housekeeper decided to look for another job.

## 102 FANCY DREAMS
While imagining herself sunbathing near the pool the maid cleaned the big windows.
While imagining himself sunbathing near the pool the maid cleaned the big windows.
While imagining herself sunbathing near the pool the housekeeper cleaned the big windows.
While imagining himself sunbathing near the pool the housekeeper cleaned the big windows.

## 103 OBESITY PROBLEMS
After reminding herself about being overweight the mother preferred healthy food.
After reminding himself about being overweight the mother preferred healthy food.
After reminding herself about being overweight the dietician preferred healthy food.
After reminding himself about being overweight the dietician preferred healthy food.

## 104 VEGGIES
After teaching herself about vegetarian food the mother began cooking more vegetables.
After teaching himself about vegetarian food the mother began cooking more vegetables.
After teaching herself about vegetarian food the dietician began cooking more vegetables.
After teaching himself about vegetarian food the dietician began cooking more vegetables.

## 105 LOST IN A GOOD BOOK
While enjoying herself with a good book the governess just ignored the noise.
While enjoying himself with a good book the governess just ignored the noise.
While enjoying herself with a good book the caregiver just ignored the noise.
While enjoying himself with a good book the caregiver just ignored the noise.

106 UNCOMFORTABLE SILENCE
While asking herself what to do the governess kept completely silent.
While asking himself what to do the governess kept completely silent.
While asking herself what to do the caregiver kept completely silent.
While asking himself what to do the caregiver kept completely silent.

107 THE PARTY AT THE MANSION
While praising herself for the successful party the baroness ignored all the gossip.
While praising himself for the successful party the baroness ignored all the gossip.
While praising herself for the successful party the socialite ignored all the gossip.
While praising himself for the successful party the socialite ignored all the gossip.

108 SUMMER VACATION
While giving herself a long break the baroness spent the summer out of town.
While giving himself a long break the baroness spent the summer out of town.
While giving herself a long break the socialite spent the summer out of town.
While giving himself a long break the socialite spent the summer out of town.

109 LEAVING
After promising herself to visit very soon the niece left the country.
After promising himself to visit very soon the niece left the country.
After promising herself to visit very soon the hairdresser left the country.
After promising himself to visit very soon the hairdresser left the country.

110 MIRROR MIRROR ON THE WALL
After checking herself again in the mirror the niece was ready to meet the family.
After checking himself again in the mirror the niece was ready to meet the family.
After checking herself again in the mirror the hairdresser was ready to meet the family.
After checking himself again in the mirror the hairdresser was ready to meet the family.

111 DANGEROUS SUN
After cautioning herself about the danger the mermaid never came back to the beach.
After cautioning himself about the danger the mermaid never came back to the beach.
After cautioning herself about the danger the sunbather never came back to the beach.
After cautioning himself about the danger the sunbather never came back to the beach.

112 AT THE BEACH
After reminding herself about the enchanted rendezvous the mermaid desperately looked for the ring.
After reminding himself about the enchanted rendezvous the mermaid desperately looked for the ring.
After reminding herself about the enchanted rendezvous the sunbather desperately looked for the ring.
After reminding himself about the enchanted rendezvous the sunbather desperately looked for the ring.

113 THE CONCERT AT THE PARK
After hurting herself during the rock concert the schoolgirl went home early.
After hurting himself during the rock concert the schoolgirl went home early.
After hurting herself during the rock concert the groupie went home early
After hurting himself during the rock concert the groupie went home early.

114 A MISSED OPPORTUNITY
After promising herself to see the next concert the schoolgirl finally calmed down.
After promising himself to see the next concert the schoolgirl finally calmed down.
After promising herself to see the next concert the groupie finally calmed down.
After promising himself to see the next concert the groupie finally calmed down.

## 115 SHORT MEMORY
After criticizing herself about being offensive the housewife easily forgot this incident.
After criticizing himself about being offensive the housewife easily forgot this incident.
After criticizing herself about being offensive the feminist easily forgot this incident.
After criticizing himself about being offensive the feminist easily forgot this incident.

## 116 DOMESTIC FRUSTRATION
After forcing herself to finish the cleaning the housewife was very frustrated.
After forcing himself to finish the cleaning the housewife was very frustrated.
After forcing herself to finish the cleaning the feminist was very frustrated.
After forcing himself to finish the cleaning the feminist was very frustrated.

## 117 FAMILY REUNION
After preparing herself to the family reunion the sister reluctantly entered the house.
After preparing himself to the family reunion the sister reluctantly entered the house.
After preparing herself to the family reunion the teenybopper reluctantly entered the house.
After preparing himself to the family reunion the teenybopper reluctantly entered the house.

## 118 BROKEN HEART
After crying herself to sleep last night the sister couldn't wake up.
After crying himself to sleep last night the sister couldn't wake up.
After crying herself to sleep last night the teenybopper couldn't wake up.
After crying himself to sleep last night the teenybopper couldn't wake up.

## 119 CONSOLATION
After consoling herself about the loss the widow became accustomed to the new situation.
After consoling himself about the loss the widow became accustomed to the new situation.
After consoling herself about the loss the librarian became accustomed to the new situation.
After consoling himself about the loss the librarian became accustomed to the new situation.

## 120 FEELING BETTER
After losing herself in work last week the widow felt better this week.
After losing himself in work last week the widow felt better this week.
After losing herself in work last week the librarian felt better this week.
After losing himself in work last week the librarian felt better this week.

## 121 FEELING COMFORTABLE
After introducing herself earlier that night the hostess felt more comfortable.
After introducing himself earlier that night the hostess felt more comfortable.
After introducing herself earlier that night the receptionist felt more comfortable.
After introducing himself earlier that night the receptionist felt more comfortable.

## 122 SMOKING BREAK
After lighting herself a cigarette outside the hostess came back in.
After lighting himself a cigarette outside the hostess came back in.
After lighting herself a cigarette outside the receptionist came back in.
After lighting himself a cigarette outside the receptionist came back in.

## 123 LEARNING FROM EXPERIENCE
After reminding herself of the previous experience the nursemaid was very stern.
After reminding himself of the previous experience the nursemaid was very stern.
After reminding herself of the previous experience the speech-therapist was very stern.
After reminding himself of the previous experience the speech-therapist was very stern.

124 SUMMER VACATION
After enjoying himself on vacation abroad the speech-therapist returned to work.
After enjoying herself on vacation abroad the speech-therapist returned to work.
After enjoying herself on vacation abroad the nursemaid returned to work.
After enjoying himself on vacation abroad the nursemaid returned to work.

125 BREAKING UP
After pouring himself another cup of tea the girlfriend said it was all over.
After pouring herself another cup of tea the girlfriend said it was all over.
After pouring himself another cup of tea the childminder said it was all over.
After pouring herself another cup of tea the childminder said it was all over.

126 IMAGINATION
After imagining herself in a wedding dress the girlfriend agreed to move in.
After imagining himself in a wedding dress the girlfriend agreed to move in.
After imagining herself in a wedding dress the childminder agreed to move in.
After imagining himself in a wedding dress the childminder agreed to move in.

127 GOOD TIME
After enjoying herself on a luxury boat the duchess came back home.
After enjoying himself on a luxury boat the duchess came back home.
After enjoying herself on a luxury boat the model came back home.
After enjoying himself on a luxury boat the model came back home.

128 CLOTHING EXPENSES
After buying herself new clothes in London the duchess was short of money.
After buying himself new clothes in London the duchess was short of money.
After buying herself new clothes in London the model was short of money.
After buying himself new clothes in London the model was short of money.

129 LOOKING GOOD
While priding herself on the new look the brunette gazed at the mirror.
While priding himself on the new look the brunette gazed at the mirror.
While priding herself on the new look the typist gazed at the mirror.
While priding himself on the new look the typist gazed at the mirror.

130 TRENDY HAIRSTYLE
After convincing herself of the trendy hairstyle the brunette took a short haircut.
After convincing himself of the trendy hairstyle the brunette took a short haircut.
After convincing herself of the trendy hairstyle the typist took a short haircut.
After convincing himself of the trendy hairstyle the typist took a short haircut.


131 AT THE CAR BOOT SALE
After finding herself unemployed for three months the dinner-lady sold handmade sweaters.
After finding himself unemployed for three months the dinner-lady sold handmade sweaters.
After finding herself unemployed for three months the knitter sold handmade sweaters.
After finding himself unemployed for three months the knitter sold handmade sweaters.

132 WARM SWEATERS
After reminding himself of last year's snow the dinner-lady prepared warm sweaters for the winter.
After reminding himself of last year's snow the dinner-lady prepared warm sweaters for the winter.
After reminding himself of last year's snow the knitter prepared warm sweaters for the winter.
After reminding himself of last year's snow the knitter prepared warm sweaters for the winter.

## 133 IN THE STORE
After buying himself a new MP3 player the daughter left the store.
After buying herself a new MP3 player the daughter left the store.
After buying himself a new MP3 player the shopper left the store.
After buying herself a new MP3 player the shopper left the store.

## 134 WELL SPENT MONEY
After promising herself to save the money the daughter purchased a new car.
After promising himself to save the money the daughter purchased a new car.
After promising herself to save the money the shopper purchased a new car.
After promising himself to save the money the shopper purchased a new car.

## 135 AT THE MATCH
Despite giving herself a sore throat the girl shouted very loud.
Despite giving himself a sore throat the girl shouted very loud.
Despite giving herself a sore throat the cheerleader shouted very loud.
Despite giving himself a sore throat the cheerleader shouted very loud.

## 136 EMBARRASSMENT
After letting herself get carried away the girl became embarrassed.
After letting himself get carried away the girl became embarrassed.
After letting herself get carried away the cheerleader became embarrassed.
After letting himself get carried away the cheerleader became embarrassed.

## 137 STRESSFUL PREPARATIONS
While preparing herself for the wedding the bride was very nervous.
While preparing himself for the wedding the bride was very nervous.
While preparing herself for the wedding the beautician was very nervous.
While preparing himself for the wedding the beautician was very nervous.

## 138 DRAMA AT THE WEDDING
After tormenting herself about the decision the bride finally ran away
After tormenting himself about the decision the bride finally ran away
After tormenting herself about the decision the beautician finally ran away
After tormenting himself about the decision the beautician finally ran away.

## 139 THE BALANCE
While writing herself a memo note the barmaid checked the balance.
While writing himself a memo note the barmaid checked the balance.
While writing herself a memo note the cashier checked the balance.
While writing himself a memo note the cashier checked the balance.

## 140 AT THE END OF THE DAY
While reminding herself to double-check the sums the barmaid counted the cash.
While reminding himself to double-check the sums the barmaid counted the cash.
While reminding herself to double-check the sums the cashier counted the cash.
While reminding himself to double-check the sums the cashier counted the cash.

## 141 VINTAGE CLOTHING
After establishing herself in the fashion business the lady opened a vintage clothing boutique.
After establishing himself in the fashion business the lady opened a vintage clothing boutique.
After establishing herself in the fashion business the weaver opened a vintage clothing boutique.
After establishing himself in the fashion business the weaver opened a vintage clothing boutique.

## 142  POPULARITY
After introducing herself at the designers' exhibition the lady became very popular.
After introducing himself at the designers' exhibition the lady became very popular.
After introducing herself at the designers' exhibition the weaver became very popular.
After introducing himself at the designers' exhibition the weaver became very popular.

## 143 MILLION POUNDS
After presenting herself at the lawyer's office the heiress got the million pounds only.
After presenting himself at the lawyer's office the heiress got the million pounds only.
After presenting herself at the lawyer's office the cleaner got the million pounds only.
After presenting himself at the lawyer's office the cleaner got the million pounds only.

## 144 THE WILL
After reassuring herself the will was legal the heiress used the inheritance money only.
After reassuring himself the will was legal the heiress used the inheritance money only.
After reassuring herself the will was legal the cleaner used the inheritance money only.
After reassuring himself the will was legal the cleaner used the inheritance money only.

## 145 SMOKING BREAK
When allowing herself a short break the nanny ignored the children's noise.
When allowing himself a short break the nanny ignored the children's noise.
When allowing herself a short break the single-parent ignored the children's noise.
When allowing himself a short break the single-parent ignored the children's noise.

## 146 NEW JOB
After finding herself a job in Edinburgh the nanny was much better off.
After finding himself a job in Edinburgh the nanny was much better off.
After finding herself a job in Edinburgh the single-parent was much better off.
After finding himself a job in Edinburgh the single-parent was much better off.

## 147 SUICIDE
Before killing herself with an overdose the stewardess wrote a suicide letter.
Before killing himself with an overdose the stewardess wrote a suicide letter.
Before killing herself with an overdose the prostitute wrote a suicide letter.
Before killing himself with an overdose the prostitute wrote a suicide letter.

## 148 ACCIDENT
After cutting herself with a table knife the stewardess was bleeding heavily.
After cutting himself with a table knife the stewardess was bleeding heavily.
After cutting herself with a table knife the prostitute was bleeding heavily.
After cutting himself with a table knife the prostitute was bleeding heavily.


## 149 SATISFACTION
When praising herself for organizing the party the aunt seemed very satisfied.
When praising himself for organizing the party the aunt seemed very satisfied.
When praising herself for organizing the party the teacher seemed very satisfied.
When praising himself for organizing the party the teacher seemed very satisfied.

## 150 RELAXING
After making herself a cup of tea the aunt slowly relaxed.
After making himself a cup of tea the aunt slowly relaxed.
After making herself a cup of tea the teacher slowly relaxed.
After making himself a cup of tea the teacher slowly relaxed.

## 151 PROFICIENCY
After establishing herself as highly professional the midwife had a lot of work.
After establishing himself as highly professional the midwife had a lot of work.
After establishing herself as highly professional the hygienist had a lot of work.
After establishing himself as highly professional the hygienist had a lot of work.

## 152 RESPONSIBILITY
After convincing herself that everything was ok the midwife left the room only.
After convincing himself that everything was ok the midwife left the room only.
After convincing herself that everything was ok the hygienist left the room only.
After convincing himself that everything was ok the hygienist left the room only.

## 153 PREPARING FOR A LONG DAY IN COURT
While preparing herself for the long day the woman got dressed.
While preparing himself for the long day the woman got dressed.
While preparing herself for the long day the assistant got dressed.
While preparing himself for the long day the assistant got dressed.

## 154 EDUCATION
After putting herself through night school the woman got a good job.
After putting himself through night school the woman got a good job.
After putting herself through night school the assistant got a good job.
After putting himself through night school the assistant got a good job.

## 155 PSYCHOLOGICAL COUNSELLING
While promising herself to improve the communication the wife prepared for the counselling meeting.
While promising himself to improve the communication the wife prepared for the counselling meeting.
While promising herself to improve the communication the therapist prepared for the counselling meeting.
While promising himself to improve the communication the therapist prepared for the counselling meeting.

## 156 AFTER THE ACCIDENT
While reminding herself not to be emotional the wife tried to be helpful.
While reminding himself not to be emotional the wife tried to be helpful.
While reminding herself not to be emotional the therapist tried to be helpful.
While reminding himself not to be emotional the therapist tried to be helpful.

## 157 PREDICTIONS
After convincing herself about the current situation the saleswoman predicted success only.
After convincing himself about the current situation the saleswoman predicted success only.
After convincing herself about the current situation the fortune-teller predicted success only.
After convincing himself about the current situation the fortune-teller predicted success only.

## 158 DAY DREAMING
After momentarily loosing herself in thought for a minute the saleswoman resumed talking.
After momentarily loosing himself in thought for a minute the saleswoman resumed talking.
After momentarily loosing herself in thought for a minute the fortune-teller resumed talking.
After momentarily loosing himself in thought for a minute the fortune-teller resumed talking.

## 159 FASHION
While priding herself for being so fashionable the grandmother was wearing an old fashioned hat.
While priding himself for being so fashionable the grandmother was wearing an old fashioned hat.
While priding herself for being so fashionable the dressmaker was wearing an old fashioned hat.
While priding himself for being so fashionable the dressmaker was wearing an old fashioned hat.

160 GOLDEN AGE

After promising herself to travel around the world the grandmother reluctantly consented to retire.
After promising himself to travel around the world the grandmother reluctantly consented to retire.
After promising herself to travel around the world the dressmaker reluctantly consented to retire.
After promising himself to travel around the world the dressmaker reluctantly consented to retire.

**Appendix C. Grandaverage plots Anaphora and Cataphora**



Grandaverage Anaphora: lexical match vs. mismatch

Lexical match = blue
Lexical mismatch = red
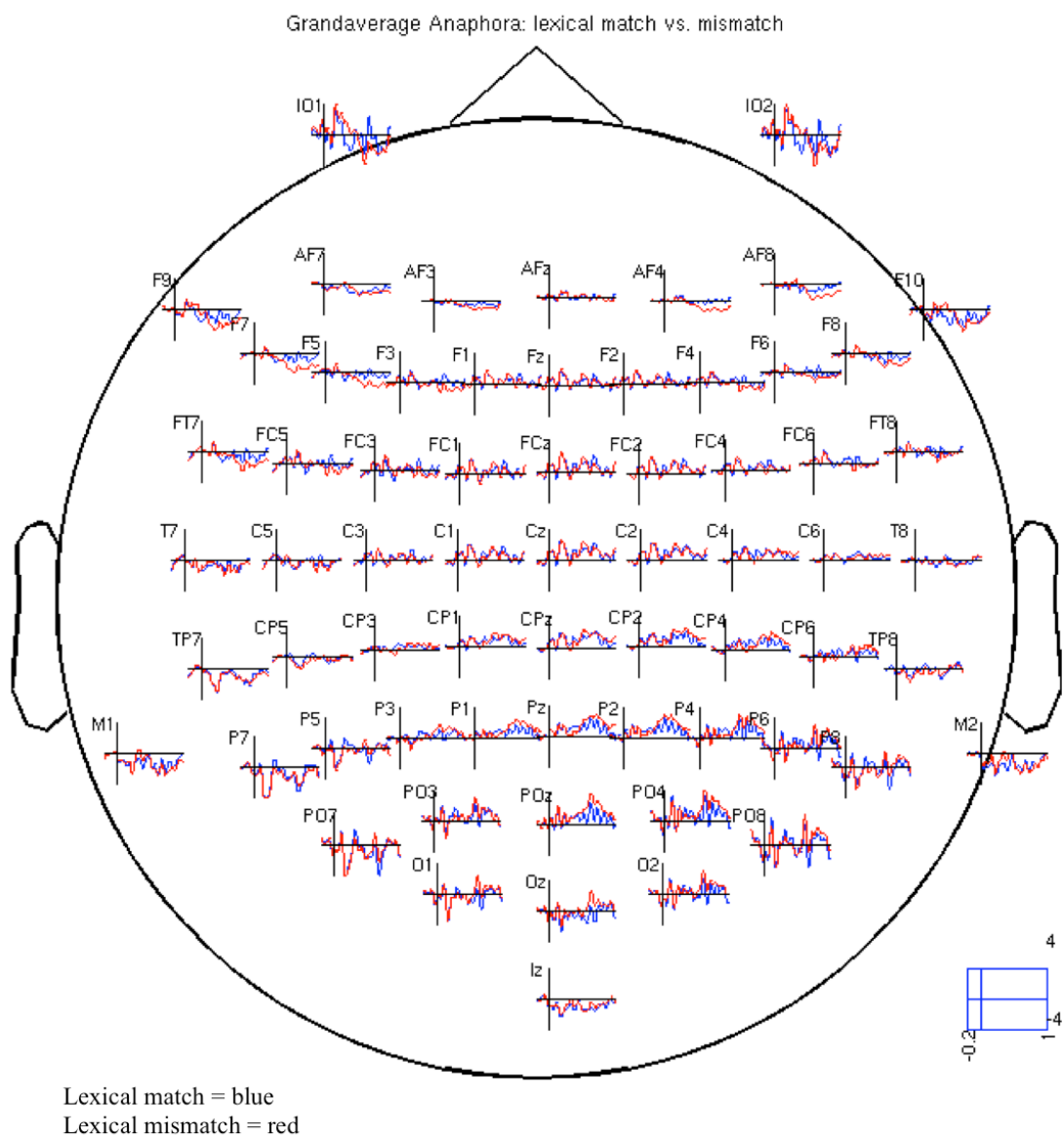
Grandaverage Anaphora: stereotypical match vs. mismatch
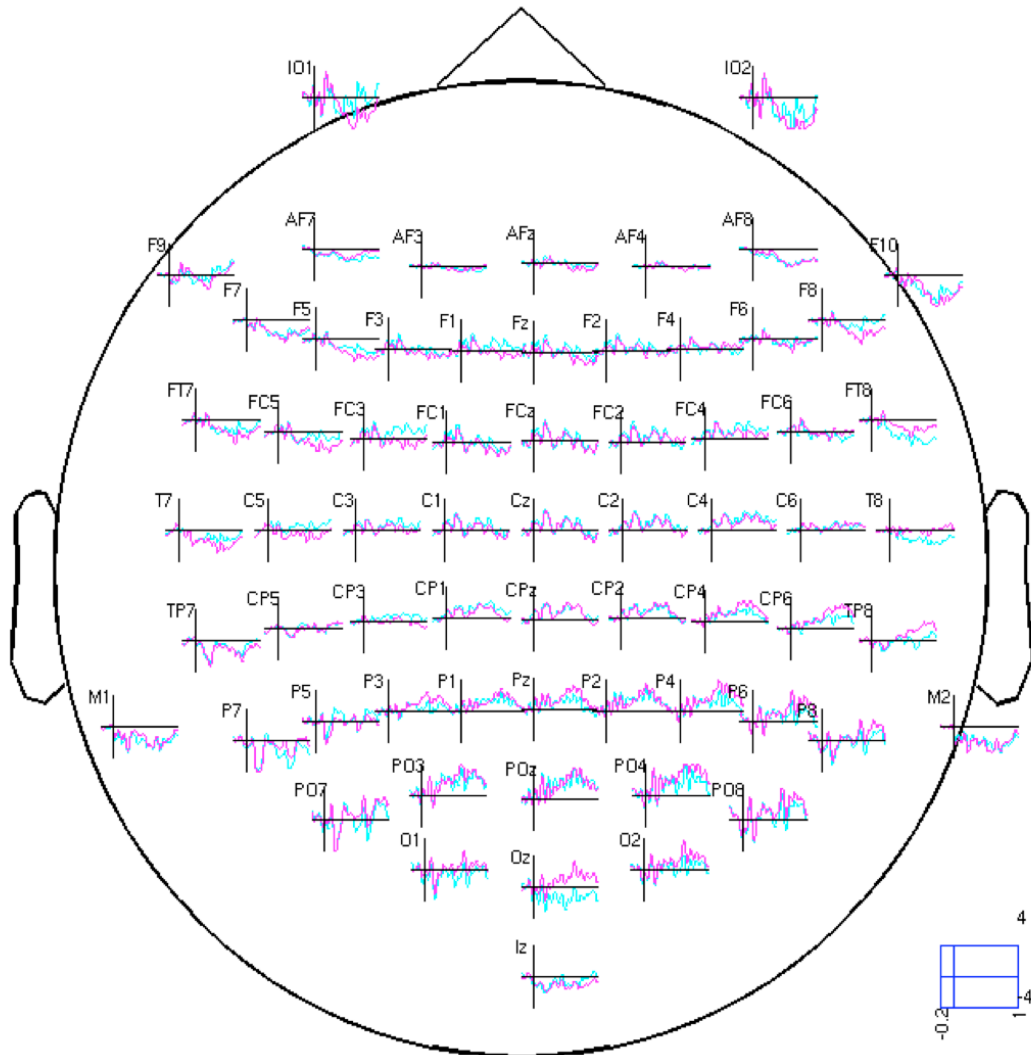
Stereotypical match = blue
Stereotypical mismatch = pink

# Grandaverage Cataphora
## Lexical mismatch - match



Lexical match = blue
Lexical mismatch = red
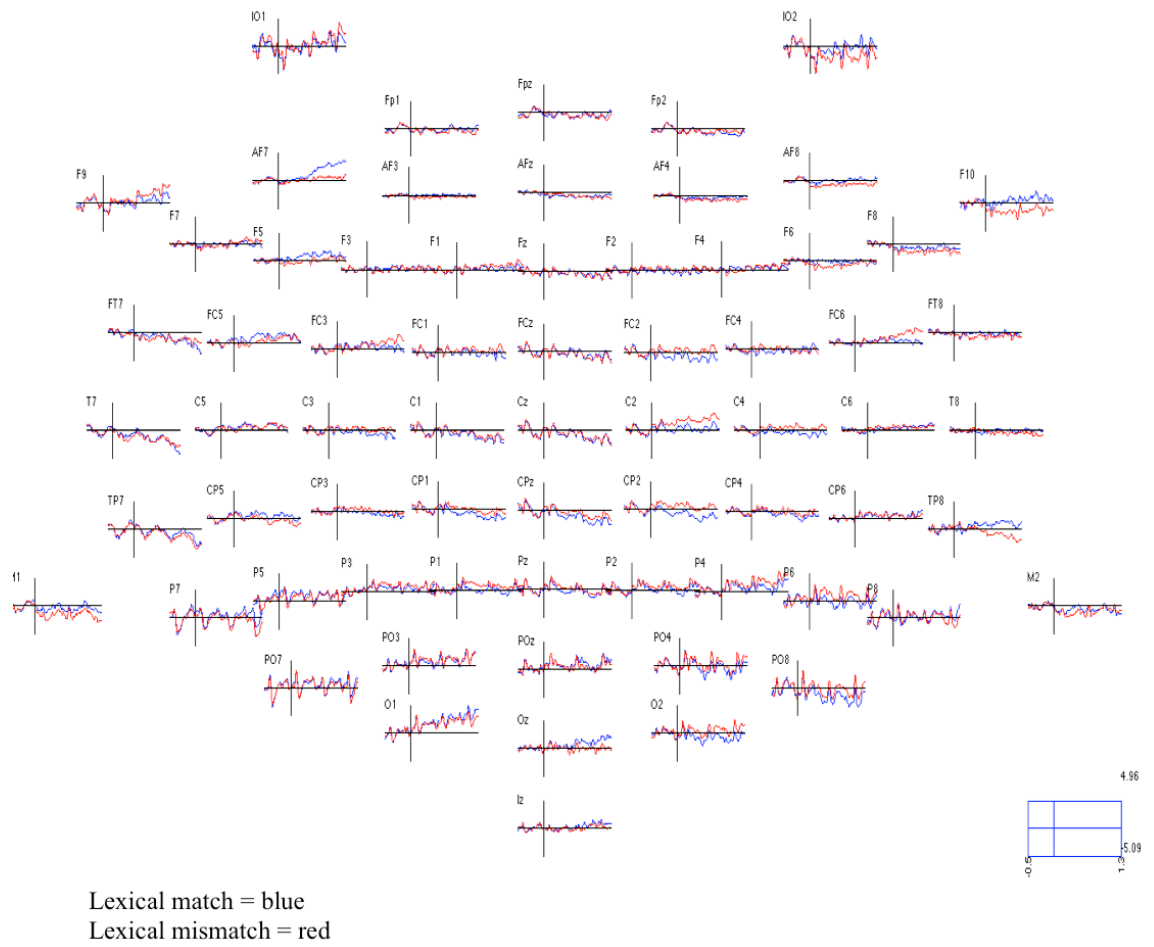
# Grandaverage Cataphora
## Stereotypical mismatch - match



Stereotypical match = blue
Stereotypical mismatch = red

**Appendix D.**

**D.1 MEG sensor layout**
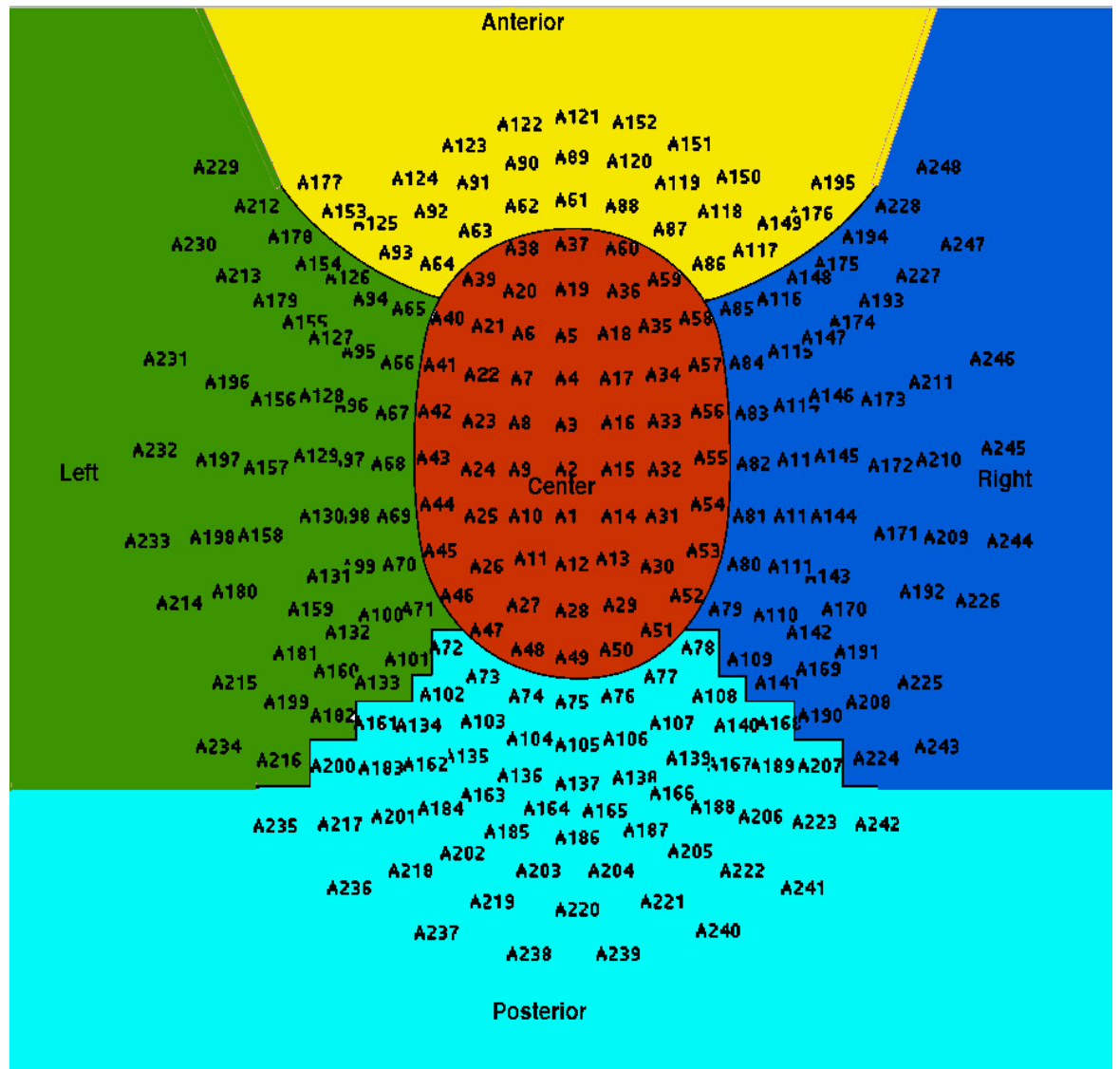
## D.2 MEG Experiment: Experimental Items

| 1 | a | Following the demanding practise the cheerleader who was carried by the boy was humming a song. |
|---|---|---|
| 1 | b | Following the demanding practise the cheerleader carried by the boy was humming a song. |
| 1 | c | The teacher noticed that the cheerleader who was carried by the boy was humming a song. |
| 1 | d | The teacher noticed that the cheerleader carried by the boy was humming a song. |
| 2 | a | After a long night the barman who was served by the waitress immediately went to bed. |
| 2 | b | After a long night the barman served by the waitress immediately went to bed |
| 2 | c | The beautician saw that the barman who was served by the waitress immediately went to bed |
| 2 | d | The beautician saw that the barman served by the waitress immediately went to bed. |
| 3 | a | Shortly before the inquiry the correspondent who was interviewed by the newswoman was optimistic. |
| 3 | b | Shortly before the inquiry the correspondent interviewed by the newswoman was optimistic. |
| 3 | c | The newspaper stated that the correspondent who was interviewed by the newswoman was optimistic. |
| 3 | d | The newspaper stated that the correspondent interviewed by the newswoman was optimistic. |
| 4 | a | In the early afternoon the manager who was fired by the client was upset. |
| 4 | b | In the early afternoon the manager fired by the client was upset. |
| 4 | c | The secretary heard that the manager who was fired by the client was upset. |
| 4 | d | The secretary heard that the manager fired by the client was upset. |
| 5 | a | Throughout the preliminary questioning the attorney who was arrested by the policeman was devastated. |
| 5 | b | Throughout the preliminary questioning the attorney arrested by the policeman was devastated. |
| 5 | c | The juror mentioned that the attorney who was arrested by the policeman was devastated. |
| 5 | d | The juror mentioned that the attorney arrested by the policeman was devastated. |
| 6 | a | Before the fatiguing negotiations the lawyer who was hired by the executive was confident. |
| 6 | b | Before the fatiguing negotiations the lawyer hired by the executive was confident. |
| 6 | c | The accountant claimed that the lawyer who was hired by the executive was confident. |
| 6 | d | The accountant claimed that the lawyer hired by the executive was confident. |
| 7 | a | After a short weekend the tutor who was instructed by the secretary was tired. |
| 7 | b | After a short weekend the tutor instructed by the secretary was tired. |
| 7 | c | The apprentice noticed that the tutor who was instructed by the secretary was tired. |
| 7 | d | The apprentice noticed that the tutor instructed by the secretary was tired. |
| 8 | a | Following the detention class the boy who was frightened by the teacher was blameless. |
| 8 | b | Following the detention class the boy frightened by the teacher was blameless. |
| 8 | c | The mother insisted that the boy who was frightened by the teacher was blameless. |
| 8 | d | The mother insisted that the boy frightened by the teacher was blameless. |
| 9 | a | During the following weeks the agent who was shot by the gunman thankfully recovered quickly. |
| 9 | b | During the following weeks the agent shot by the gunman thankfully recovered quickly. |
| 9 | c | The doctor confirmed that the agent who was shot by the gunman thankfully recovered quickly. |
| 9 | d | The doctor confirmed that the agent shot by the gunman thankfully recovered quickly. |
| 10 | a | On several strange occasions the priest who was interrogated by the policeman was suspicious. |
| 10 | b | On several strange occasions the priest interrogated by the policeman was suspicious. |
| 10 | c | The reporter thought that the priest who was interrogated by the policeman was suspicious. |
| 10 | d | The reporter thought that the priest interrogated by the policeman was suspicious. |
| 11 | a | A week ago today the farmer who was compensated by the investor went on holiday. |
| 11 | b | A week ago today the farmer compensated by the investor went on holiday. |
| 11 | c | The woman knew that the farmer who was compensated by the investor went on holiday. |
| 11 | d | The woman knew that the farmer compensated by the investor went on holiday. |
| 12 | a | Several hours after lunchtime the man who was accused by the detective was finally convicted. |
| 12 | b | Several hours after lunchtime the man accused by the detective was finally convicted. |
| 12 | c | The witness heard that the man who was accused by the detective was finally convicted. |

| 12 | d | The witness heard that the man accused by the detective was finally convicted. |
| 13 | a | Before the final exams the Professor who was evaluated by the students was pessimistic. |
| 13 | b | Before the final exams the Professor evaluated by the students was pessimistic. |
| 13 | c | The Dean noticed that the Professor who was evaluated by the students was pessimistic. |
| 13 | d | The Dean noticed that the Professor evaluated by the students was pessimistic. |
| 14 | a | Prior to the incident the prisoner who was punished by the detective seemed nervous. |
| 14 | b | Prior to the incident the prisoner punished by the detective seemed nervous. |
| 14 | c | The ward claimed that the prisoner who was punished by the detective seemed nervous. |
| 14 | d | The ward claimed that the prisoner punished by the detective seemed nervous. |
| 15 | a | Once every two weeks the poet who was studied by the postgraduate wrote limericks. |
| 15 | b | Once every two weeks the poet studied by the postgraduate wrote limericks. |
| 15 | c | The girl thought that the poet who was studied by the postgraduate wrote limericks. |
| 15 | d | The girl thought that the poet studied by the postgraduate wrote limericks. |
| 16 | a | Before the Christmas holidays the illusionist who was worshipped by the audience received knighthood. |
| 16 | b | Before the Christmas holidays the illusionist worshipped by the audience received knighthood. |
| 16 | c | The agent mentioned that the illusionist who was worshipped by the audience received knighthood. |
| 16 | d | The agent mentioned that the illusionist worshipped by the audience received knighthood. |
| 17 | a | Following the press conference the politician who was kicked by the activist was injured. |
| 17 | b | Following the press conference the politician kicked by the activist was injured. |
| 17 | c | The BBC reported that the politician who was kicked by the activist was injured. |
| 17 | d | The BBC reported that the politician kicked by the activist was injured. |
| 18 | a | Close to the tournament the footballer who was taught by the coach was injured. |
| 18 | b | Close to the tournament the footballer taught by the coach was injured. |
| 18 | c | The teacher realized that the footballer who was taught by the coach was injured. |
| 18 | d | The teacher realized that the footballer taught by the coach was injured. |
| 19 | a | After several long months the barrister who was convicted by the judge was found innocent. |
| 19 | b | After several long months the barrister convicted by the judge was found innocent. |
| 19 | c | The reporter believed that the barrister who was convicted by the judge was found innocent. |
| 19 | d | The reporter believed that the barrister convicted by the judge was found innocent. |
| 20 | a | On the previous Monday the teacher who was terrorized by the teenagers quit his job. |
| 20 | b | On the previous Monday the teacher terrorized by the teenagers quit his job. |
| 20 | c | The principal said that the teacher who was terrorized by the teenagers quit his job. |
| 20 | d | The principal said that the teacher terrorized by the teenagers quit his job. |
| 21 | a | Towards the final verdict the juror who was questioned by the examiner was nervous. |
| 21 | b | Towards the final verdict the juror questioned by the examiner was nervous. |
| 21 | c | The man saw that the juror who was questioned by the examiner was nervous. |
| 21 | d | The man saw that the juror questioned by the examiner was nervous. |
| 22 | a | A week ago today the tutor who was lectured by the headmaster got in trouble. |
| 22 | b | A week ago today the tutor lectured by the headmaster got in trouble. |
| 22 | c | The student heard that the tutor who was lectured by the headmaster got in trouble. |
| 22 | d | The student heard that the tutor lectured by the headmaster got in trouble. |
| 23 | a | In the late afternoon the actress who was photographed by the reporter was flattered. |
| 23 | b | In the late afternoon the actress photographed by the reporter was flattered. |
| 23 | c | The tourist spotted that the actress who was photographed by the reporter was flattered. |
| 23 | d | The tourist spotted that the actress photographed by the reporter was flattered. |
| 24 | a | At lunchtime that day the boy who was chased by the shopkeeper was panicking. |
| 24 | b | At lunchtime that day the boy chased by the shopkeeper was panicking. |
| 24 | c | The onlooker saw that the boy who was chased by the shopkeeper was panicking. |
| 24 | d | The onlooker saw that the boy chased by the shopkeeper was panicking. |
| 25 | a | The week before last the chef who was dismissed by the hotelier was furious. |
| 25 | b | The week before last the chef dismissed by the hotelier was furious. |
| 25 | c | The maid confirmed that the chef who was dismissed by the hotelier was furious. |
| 25 | d | The maid confirmed that the chef dismissed by the hotelier was furious. |
| 26 | a | After the suspicious incident the investor who was investigated by the police left the country. |
| 26 | b | After the suspicious incident the investor investigated by the police tried left the country. |

| 26 | c | The detective reported that the investor who was investigated by the police left the country. |
|----|---|-----------------------------------------------------------------------------------------------|
| 26 | d | The detective reported that the investor investigated by the police left the country. |
| 27 | a | After a light dinner the tourist who was searched by the bouncer went home. |
| 27 | b | After a light dinner the tourist searched by the bouncer went home. |
| 27 | c | The girl presumed that the tourist who was searched by the bouncer went home. |
| 27 | d | The girl presumed that the tourist searched by the bouncer went home. |
| 28 | a | On Monday last week the nurse who was examined by the doctor was not on duty. |
| 28 | b | On Monday last week the nurse examined by the doctor was not on duty. |
| 28 | c | The receptionist noted that the nurse who was examined by the doctor was not on duty. |
| 28 | d | The receptionist noted that the nurse examined by the doctor was not on duty. |
| 29 | a | For already four months the dancer who was invited by her friend was secretly in love with him. |
| 29 | b | For already four months the dancer invited by her friend was secretly in love with him. |
| 29 | c | The roommate knew that the dancer who was invited by her friend was secretly in love with him. |
| 29 | d | The roommate knew that the dancer invited by her friend was secretly in love with him. |
| 30 | a | In the early hours the man who was rescued by the firemen was treated for smoke inhalation. |
| 30 | b | In the early hours the man rescued by the firemen was treated for smoke inhalation. |
| 30 | c | The nurse said that the man who was rescued by the firemen was treated for smoke inhalation. |
| 30 | d | The nurse said that the man rescued by the firemen was immediately for smoke inhalation. |
| 31 | a | Before the short break the therapist who was hypnotized by the illusionist couldn't stop singing. |
| 31 | b | Before the short break the therapist hypnotized by the illusionist couldn't stop singing. |
| 31 | c | The husband heard that the therapist who was hypnotized by the illusionist couldn't stop singing. |
| 31 | d | The husband heard that the therapist hypnotized by the illusionist couldn't stop singing. |
| 32 | a | After the hearing today the criminal who was tortured by the CIA was uncooperative. |
| 32 | b | After the hearing today the criminal tortured by the CIA was uncooperative. |
| 32 | c | The lawyer claimed that the criminal who was tortured by the CIA was uncooperative. |
| 32 | d | The lawyer claimed that the criminal tortured by the CIA was uncooperative. |
| 33 | a | In the early seventies the attorney who was sentenced by the court was engaged in fraud. |
| 33 | b | In the early seventies the attorney sentenced by the court was engaged in fraud. |
| 33 | c | The judge confirmed that the attorney who was sentenced by the court was engaged in fraud. |
| 33 | d | The judge confirmed that the attorney sentenced by the court was engaged in fraud. |
| 34 | a | After six long months the surgeon who was cured by the physician felt better. |
| 34 | b | After six long months the surgeon cured by the physician felt better. |
| 34 | c | The receptionist believed that the surgeon who was cured by the physician felt better. |
| 34 | d | The receptionist believed that the surgeon cured by the physician felt better. |
| 35 | a | Yesterday in the morning the counsellor who was convicted by the jury ran away. |
| 35 | b | Yesterday in the morning the counsellor convicted by the jury ran away. |
| 35 | c | The reporter knew that the counsellor who was convicted by the jury ran away. |
| 35 | d | The reporter knew that the counsellor convicted by the jury ran away. |
| 36 | a | On a cold afternoon the postgraduate who was graded by the examiner was petrified. |
| 36 | b | On a cold afternoon the postgraduate graded by the examiner was petrified. |
| 36 | c | The secretary mentioned that the postgraduate who was graded by the examiner was petrified. |
| 36 | d | The secretary mentioned that the postgraduate graded by the examiner was petrified. |
| 37 | a | During the last game the football-player who was lifted by the supporters had played well. |
| 37 | b | During the last game the football-player lifted by the supporters had played well. |
| 37 | c | The coach thought that the football-player who was lifted by the supporters had played well. |
| 37 | d | The coach thought that the football-player lifted by the supporters had played well. |
| 38 | a | Once every two weeks the presenter who was entertained by the comedian went for a run. |
| 38 | b | Once every two weeks the presenter entertained by the comedian went for a run. |
| 38 | c | The director thought that the presenter who was entertained by the comedian went for a run. |
| 38 | d | The director thought that the presenter entertained by the comedian went for a run. |
| 39 | a | Almost every three month the model who was admired by the photographer went to L.A. |
| 39 | b | Almost every three month the model admired by the photographer went to L.A.. |

| 39 | c | The singer believed that the model who was admired by the photographer went to L.A.. |
|---|---|---|
| 39 | d | The singer believed that the model admired by the photographer went to L.A.. |
| 40 | a | As early as today the goalkeeper who was kissed by the cheerleader fell in love. |
| 40 | b | As early as today the goalkeeper kissed by the cheerleader fell in love. |
| 40 | c | The friend knew that the goalkeeper who was kissed by the cheerleader fell in love. |
| 40 | d | The friend knew that the goalkeeper kissed by the cheerleader fell in love. |
| 41 | a | The year before last the lawyer who was remembered by the investor moved to Spain. |
| 41 | b | The year before last the lawyer remembered by the investor moved to Spain. |
| 41 | c | The executive mentioned that the lawyer who was remembered by the investor moved to Spain. |
| 41 | d | The executive mentioned that the lawyer remembered by the investor moved to Spain. |
| 42 | a | At the lunchtime break the student who was warned by the principal was cheeky. |
| 42 | b | At the lunchtime break the student warned by the principal was cheeky. |
| 42 | c | The administrator indicated that the student who was warned by the principal was cheeky. |
| 42 | d | The administrator indicated that the student warned by the principal was cheeky. |
| 43 | a | Usually during the weekend the poet who was explored by the students wrote intriguing ballads. |
| 43 | b | Usually during the weekend the poet explored by the students wrote intriguing ballads. |
| 43 | c | The professor said that the poet who was explored by the students wrote intriguing ballads. |
| 43 | d | The professor said that the poet explored by the students wrote intriguing ballads. |
| 44 | a | Saturday two weeks ago the teenager who was found by the relative went to the pub on her own. |
| 44 | b | Saturday two weeks ago the teenager found by the relative went to the pub on her own. |
| 44 | c | The neighbour heard that the teenager who was found by the relative went to the pub on her own. |
| 44 | d | The neighbour heard that the teenager found by the relative went to the pub on her own. |
| 45 | a | Tuesday two days ago the banker who was murdered by the burglar was found. |
| 45 | b | Tuesday two days ago the banker murdered by the burglar was found. |
| 45 | c | The witness reported that the banker who was murdered by the burglar was found. |
| 45 | d | The witness reported that the banker murdered by the burglar was found. |
| 46 | a | During the long interview the politician who was persuaded by the vice-president was overconfident. |
| 46 | b | During the long interview the politician persuaded by the vice-president was overconfident. |
| 46 | c | The reporter knew that the politician who was persuaded by the vice-president was overconfident. |
| 46 | d | The reporter knew that the politician persuaded by the vice-president was overconfident. |
| 47 | a | As soon as possible the coroner who was convinced by the barrister agreed to appear in court. |
| 47 | b | As soon as possible the coroner convinced by the barrister agreed to appear in court. |
| 47 | c | The judge acknowledged that the coroner who was convinced by the barrister agreed to appear in court. |
| 47 | d | The judge acknowledged that the coroner convinced by the barrister agreed to appear in court. |
| 48 | a | A week ago yesterday the driver who was stopped by the patrol was drunk. |
| 48 | b | A week ago yesterday the driver stopped by the patrol was drunk. |
| 48 | c | The mayor noticed that the driver who was stopped by the patrol was drunk. |
| 48 | d | The mayor noticed that the driver stopped by the patrol was drunk. |
| 49 | a | Before the summer holidays the builder who was instructed by the architect was promoted. |
| 49 | b | Before the summer holidays the builder instructed by the architect was promoted. |
| 49 | c | The construction-worker said that the builder who was instructed by the architect was promoted. |
| 49 | d | The construction-worker said that the builder instructed by the architect was promoted. |
| 50 | a | Only three years ago the watchmaker who was helped by his apprentice used to work in light engineering. |
| 50 | b | Only three years ago the watchmaker helped by his apprentice used to work in light engineering. |
| 50 | c | The janitor said that the watchmaker who was helped by his apprentice used to work in light engineering. |

| 50 | d | The janitor said that the watchmaker helped by his apprentice used to work in light engineering. |
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| 51 | a | Just two minutes ago the basketball-player who was pushed by his rival was angry. |
| 51 | b | Just two minutes ago the basketball-player pushed by his rival was angry. |
| 51 | c | The referee saw that the basketball-player who was pushed by his rival was angry. |
| 51 | d | The referee saw that the basketball-player pushed by his rival was angry. |
| 52 | a | In the early morning the protester who was punched by the scientologist was hospitalized. |
| 52 | b | In the early morning the protester punched by the scientologist was hospitalized. |
| 52 | c | The bystander remarked that the protester who was punched by the scientologist was hospitalized. |
| 52 | d | The bystander remarked that the protester punched by the scientologist was hospitalized. |
| 53 | a | Almost two years ago the bishop who was assisted by the priest was principal celebrant at the Advent Mass. |
| 53 | b | Almost two years ago the bishop assisted by the priest was principal celebrant at the Advent Mass. |
| 53 | c | The woman saw that the bishop who was assisted by the priest was principal celebrant at the Advent Mass. |
| 53 | d | The woman saw that the bishop assisted by the priest was principal celebrant at the Advent Mass. |
| 54 | a | During the whole seminar the economist who was tutored by the lecturer was bored. |
| 54 | b | During the whole seminar the economist tutored by the lecturer was bored. |
| 54 | c | The student noticed that the economist who was tutored by the lecturer was bored. |
| 54 | d | The student noticed that the economist tutored by the lecturer was bored. |
| 55 | a | On the previous weekend the cardiologist who was advised by his colleague had paid for a large mansion. |
| 55 | b | On the previous weekend the cardiologist advised by his colleague had paid for a large mansion. |
| 55 | c | The wife said that the cardiologist who was advised by his colleague had paid for a large mansion. |
| 55 | d | The wife said that the cardiologist advised by his colleague had paid for a large mansion. |
| 56 | a | Always on a Thursday the singer who was recorded by the producer got a haircut. |
| 56 | b | Always on a Thursday the singer recorded by the producer got a haircut. |
| 56 | c | The violinist saw that the singer who was recorded by the producer got a haircut. |
| 56 | d | The violinist saw that the singer recorded by the producer got a haircut. |
| 57 | a | After a long run the athlete who was trained by the manager was exhausted. |
| 57 | b | After a long run the athlete trained by the manager was exhausted. |
| 57 | c | The photographer said that the athlete who was trained by the manager was exhausted. |
| 57 | d | The photographer said that the athlete trained by the manager was exhausted. |
| 58 | a | Occasionally on the weekend the vicar's-wife who was painted by the artist worked at the library. |
| 58 | b | Occasionally on the weekend the vicar's-wife painted by the artist worked at the library. |
| 58 | c | The milkman mentioned that the vicar's-wife who was painted by the artist worked at the library. |
| 58 | d | The milkman mentioned that the vicar's-wife painted by the artist worked at the library. |
| 59 | a | Usually once a week the captain who was loved by his crew shared his expensive whiskey. |
| 59 | b | Usually once a week the captain loved by his crew shared his expensive whiskey. |
| 59 | c | The officer believed  that the captain who was loved by his crew shared his expensive whiskey. |
| 59 | d | The officer believed that the captain loved by his crew shared his expensive whiskey. |
| 60 | a | In the early afternoon the participant who was expected by the experimenter was late. |
| 60 | b | In the early afternoon the participant expected by the experimenter was late. |
| 60 | c | The secretary realized that the participant who was expected by the experimenter was late. |
| 60 | d | The secretary realized that the participant expected by the experimenter was late. |
| 61 | a | Frequently on sunny afternoons the guide who was followed by the tourists went to the park. |
| 61 | b | Frequently on sunny afternoons the guide followed by the tourists went to the park. |
| 61 | c | The woman saw that the guide who was followed by the tourists went to the park. |
| 61 | d | The woman saw that the guide followed by the tourists went to the park. |
| 62 | a | For over two decades the dictator who was hated by the people was cruel. |

| 62 | b | For over two decades the dictator hated by the people was cruel. |
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| 62 | c | The ambassador admitted that the dictator who was hated by the people was cruel. |
| 62 | d | The ambassador admitted that the dictator hated by the people was cruel. |
| 63 | a | On the previous day the secretary who was intimidated by her boss started crying. |
| 63 | b | On the previous day the secretary intimidated by her boss started crying. |
| 63 | c | The assistant realized that the secretary who was intimidated by her boss started crying. |
| 63 | d | The assistant realized that the secretary intimidated by her boss started crying. |
| 64 | a | Roughly two years ago the chef who was recommended by the critic specialized in French cuisine. |
| 64 | b | Roughly two years ago the chef recommended by the critic specialized in French cuisine. |
| 64 | c | The hotelier heard that the chef who was recommended by the critic specialized in French cuisine. |
| 64 | d | The hotelier heard that the chef recommended by the critic specialized in French cuisine. |
| 65 | a | After the long holiday the conductor who was casted by the theatre received a prize. |
| 65 | b | After the long holiday the conductor casted by the theatre received a prize. |
| 65 | c | The singer heard that the conductor who was casted by the theatre received a prize. |
| 65 | d | The singer heard that the conductor casted by the theatre received a prize. |
| 66 | a | During the short break the athlete who was trained by the instructor was exhausted. |
| 66 | b | During the short break the athlete trained by the instructor was exhausted. |
| 66 | c | The scout saw that the athlete who was trained by the instructor was exhausted. |
| 66 | d | The scout saw that the athlete trained by the instructor was exhausted. |
| 67 | a | Throughout the meticulous questioning the solicitor who was appointed by the hospital was too defensive. |
| 67 | b | Throughout the meticulous questioning the solicitor appointed by the hospital was too defensive. |
| 67 | c | The doctor believed that the solicitor who was appointed by the hospital was too defensive. |
| 67 | d | The doctor believed that the solicitor appointed by the hospital was too defensive. |
| 68 | a | On Tuesday last week the lawyer who was confused by the colleague filed a protest. |
| 68 | b | On Tuesday last week the lawyer confused by the colleague filed a protest. |
| 68 | c | The journalist knew that the lawyer who was confused by the colleague filed a protest. |
| 68 | d | The journalist knew that the lawyer confused by the colleague filed a protest. |
| 69 | a | After the shameful episode the assistant who was embarrassed by the affair was distressed. |
| 69 | b | After the shameful episode the assistant embarrassed by the affair was distressed. |
| 69 | c | The librarian confirmed that the assistant who was embarrassed by the affair was distressed . |
| 69 | d | The librarian confirmed that the assistant embarrassed by the affair was distressed. |
| 70 | a | Yesterday in the afternoon the contestant who was teased by the judge was almost crying. |
| 70 | b | Yesterday in the afternoon the contestant teased by the judge was almost crying. |
| 70 | c | The cameraman saw that the contestant who was teased by the judge was almost crying. |
| 70 | d | The cameraman saw that the contestant teased by the judge was almost crying. |
| 71 | a | In the early morning the ambassador who was welcomed by the representative had come from France. |
| 71 | b | In the early afternoon the ambassador welcomed by the representative had come from France. |
| 71 | c | The reporter knew that the ambassador who was welcomed by the representative had come from France. |
| 71 | d | The reporter knew that the ambassador welcomed by the representative had come from France. |
| 72 | a | At dinner last night the singer who was introduced by the musician was arrogant. |
| 72 | b | At dinner last night the singer introduced by the musician was arrogant. |
| 72 | c | The composer heard that the singer who was introduced by the musician was arrogant. |
| 72 | d | The composer heard that the singer introduced by the musician was arrogant. |
| 73 | a | At the important meeting the minister who was elected by the priest was delighted. |
| 73 | b | At the important meeting the minister elected by the priest was delighted. |
| 73 | c | The correspondent said that the minister who was elected by the priest was delighted. |
| 73 | d | The correspondent said that the minister elected by the priest was delighted. |
| 74 | a | During the whole weekend the scientist who was rejected by the journal was fuming. |
| 74 | b | During the whole weekend the scientist rejected by the journal was fuming. |
| 74 | c | The editor noticed that the scientist who was rejected by the journal was fuming. |
| 74 | d | The editor noticed that the scientist rejected by the journal was fuming. |
| 75 | a | After the serious incident the shopkeeper who was injured by the robber was screaming. |

| 75 | b | After the serious incident the shopkeeper injured by the robber was screaming. |
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| 75 | c | The detective reported that the shopkeeper who was injured by the robber was screaming. |
| 75 | d | The detective reported that the shopkeeper injured by the robber was screaming. |
| 76 | a | Just three days ago the accountant who was betrayed by his wife asked for a divorce. |
| 76 | b | Just three days ago the accountant betrayed by his wife asked for a divorce. |
| 76 | c | The neighbour knew that the accountant who was betrayed by his wife asked for a divorce. |
| 76 | d | The neighbour knew that the accountant betrayed by his wife asked for a divorce. |
| 77 | a | On Sunday after breakfast the athlete who was saved by the lifeguard almost drowned in the dangerous current. |
| 77 | b | On Sunday after breakfast the athlete saved by the lifeguard almost drowned in the dangerous current. |
| 77 | c | The doctor explained that the athlete who was saved by the lifeguard almost drowned in the dangerous current. |
| 77 | d | The doctor explained that the athlete saved by the lifeguard almost drowned in the dangerous current. |
| 78 | a | For almost twenty years the agent who was monitored by the General worked for the CIA. |
| 78 | b | For almost twenty years the agent monitored by the General worked for the CIA. |
| 78 | c | The spy revealed that the agent who was monitored by the General worked for the CIA. |
| 78 | d | The spy revealed that the agent monitored by the General worked for the CIA. |
| 79 | a | Last week at noon the customer who was offended by the shopkeeper was accused of stealing. |
| 79 | b | Last week at noon the customer offended by the shopkeeper was accused of stealing. |
| 79 | c | The woman saw that the customer who was offended by the shopkeeper was accused of stealing. |
| 79 | d | The woman saw that the customer offended by the shopkeeper was accused of stealing. |
| 80 | a | Last night before dinner the wife who was quizzed by the police was rather nervous. |
| 80 | b | Last night before dinner the wife quizzed by the police was rather nervous. |
| 80 | c | The private-investigator believed that the wife who was quizzed by the police was rather nervous. |
| 80 | d | The private-investigator believed that the wife quizzed by the police was rather nervous. |
| 81 | a | At the important game the cricket-player who was angered by the referee was disrespectful. |
| 81 | b | At the important game the cricket-player angered by the referee was disrespectful. |
| 81 | c | The news writer thought that the cricket-player who was angered by the referee was disrespectful. |
| 81 | d | The news writer thought that the cricket-player angered by the referee was disrespectful. |
| 82 | a | After the delicious dinner the editor who was impressed by the writer was easy to please. |
| 82 | b | After the delicious dinner the editor impressed by the writer was easy to please. |
| 82 | c | The reviewer assumed that the editor who was impressed by the writer was easy to please. |
| 82 | d | The reviewer assumed that the editor impressed by the writer was easy to please. |
| 83 | a | Just a minute ago the girl who was cuddled by the mother was laughing. |
| 83 | b | Just a minute ago the girl cuddled by the mother was laughing. |
| 83 | c | The waitress saw that the girl who was cuddled by the mother was laughing. |
| 83 | d | The waitress saw that the girl cuddled by the mother was laughing. |
| 84 | a | Last year in autumn the journalist who was respected by the broadcaster was part of a big scandal. |
| 84 | b | Last year in autumn the journalist respected by the broadcaster was part of a big scandal. |
| 84 | c | The priest knew that the journalist who was respected by the broadcaster was part of a big scandal. |
| 84 | d | The priest knew that the journalist respected by the broadcaster was part of a big scandal. |
| 85 | a | Since summer this year the boy who was adored by the cheerleader was in love with her. |
| 85 | b | Since summer this year the boy adored by the cheerleader was in love with her. |
| 85 | c | The friend noticed that the boy who was adored by the cheerleader was in love with her. |
| 85 | d | The friend noticed that the boy adored by the cheerleader was in love with her. |
| 86 | a | During the fight today the cage-fighter who was aggravated by the challenger was having trouble breathing. |
| 86 | b | During the fight today the cage-fighter aggravated by the challenger was having trouble breathing. |
| 86 | c | The referee realized that the cage-fighter who was aggravated by the challenger was having trouble breathing. |
| 86 | d | The referee realized that the cage-fighter aggravated by the challenger was having trouble |

| | | breathing. |
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| 87 | a | Very early this morning the food-critic who was poisoned by the chef was rushed to hospital. |
| 87 | b | Very early this morning the food-critic poisoned by the chef was rushed to hospital. |
| 87 | c | The busboy mentioned that the food-critic who was poisoned by the chef was rushed to hospital. |
| 87 | d | The busboy mentioned that the food-critic poisoned by the chef was rushed to hospital. |
| 88 | a | Late on Saturday night the teenager who was removed by the bouncer was furious. |
| 88 | b | Late on Saturday night the teenager removed by the bouncer was furious. |
| 88 | c | The girlfriend claimed that the teenager who was removed by the bouncer was furious. |
| 88 | d | The girlfriend claimed that the teenager removed by the bouncer was furious. |
| 89 | a | In the early afternoon the salesman who was helped by the assistant was surprised. |
| 89 | b | In the early afternoon the salesman helped by the assistant was surprised. |
| 89 | c | The customer thought that the salesman who was helped by the assistant was surprised. |
| 89 | d | The customer thought that the salesman helped by the assistant was surprised. |
| 90 | a | Soon after the meeting the Prime Minister who was nominated by the committee felt privileged. |
| 90 | b | Soon after the meeting the Prime Minister nominated by the committee felt privileged. |
| 90 | c | The Chancellor learned that the Prime Minister who was nominated by the committee felt privileged. |
| 90 | d | The Chancellor learned that the Prime Minister nominated by the committee felt privileged. |
| 91 | a | For almost a year the secretary who was bullied by the colleagues was unhappy. |
| 91 | b | For almost a year the secretary bullied by the colleagues was unhappy. |
| 91 | c | The cleaner heard that the secretary who was bullied by the colleagues was unhappy. |
| 91 | d | The cleaner heard that the secretary bullied by the colleagues was unhappy. |
| 92 | a | Almost three months ago the trader who was influenced by the banker started a new business. |
| 92 | b | Almost three months ago the trader influenced by the banker started a new business. |
| 92 | c | The consultant mentioned that the trader who was influenced by the banker started a new business. |
| 92 | d | The consultant mentioned that the trader influenced by the banker started a new business. |
| 93 | a | After ten long years the singer who was amused by the writer wrote two hit-songs. |
| 93 | b | After ten long years the singer amused by the writer wrote two hit-songs. |
| 93 | c | The agent heard that the singer who was amused by the writer wrote two hit-songs. |
| 93 | d | The agent heard that the singer amused by the writer had written two hit-songs. |
| 94 | a | During the last hour the contractor who was represented by the lawyer was not listening. |
| 94 | b | During the last hour the contractor represented by the lawyer was not listening. |
| 94 | c | The taxi-driver realized that the contractor who was represented by the lawyer was not listening. |
| 94 | d | The taxi-driver realized that the contractor represented by the lawyer was not listening. |
| 95 | a | Early on Saturday night the teenager who was dressed by her mother looked stunning. |
| 95 | b | Early on Saturday night the teenager dressed by her mother looked stunning. |
| 95 | c | The father thought that the teenager who was dressed by her mother looked stunning. |
| 95 | d | The father thought that the teenager dressed by her mother looked stunning. |
| 96 | a | Before dawn on Wednesday the air force who was destroyed by the allies fired the missiles. |
| 96 | b | Before dawn on Wednesday the air force destroyed by the allies fired the missiles. |
| 96 | c | The journalist said that the air force who was destroyed by the allies fired the missiles. |
| 96 | d | The journalist said that the air force destroyed by the allies fired the missiles. |
| 97 | a | After only one month the shoplifter who was hunted by the sergeant was imprisoned. |
| 97 | b | After only one month the shoplifter hunted by the sergeant was imprisoned. |
| 97 | c | The clerk remembered that the shoplifter who was hunted by the sergeant was imprisoned. |
| 97 | d | The clerk remembered that the shoplifter hunted by the sergeant was imprisoned. |
| 98 | a | Yesterday in the afternoon the doctor who was charged by the bank was furious. |
| 98 | b | Yesterday in the afternoon the doctor charged by the bank was furious. |
| 98 | c | The clerk noticed that the doctor who was charged by the bank was furious. |
| 98 | d | The clerk noticed that the doctor charged by the bank was furious. |
| 99 | a | This morning at school the boy who was attacked by the dog was frightened to death. |
| 99 | b | This morning at school the boy attacked by the dog was frightened to death. |
| 99 | c | The mailman noticed that the boy who was attacked by the dog was frightened to death. |
| 99 | d | The mailman noticed that the boy attacked by the dog was frightened to death. |
| 100 | a | On a warm afternoon the consultant who was called by the dentist was not available. |

| 100 | b | On a warm afternoon the consultant called by the dentist was not available. |
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| 100 | c | The receptionist said that the consultant who was called by the dentist was not available. |
| 100 | d | The receptionist said that the consultant called by the dentist was not available. |
| 101 | a | This morning at kindergarten the child who was hugged by the nurse was much better again. |
| 101 | b | This morning at kindergarten the child hugged by the nurse was much better again. |
| 101 | c | The brother claimed that the child who was hugged by the nurse was much better again. |
| 101 | d | The brother claimed that the child hugged by the nurse was much better again. |
| 102 | a | Late on Thursday night the hunter who was approached by the boar was nervous. |
| 102 | b | Late on Thursday night the hunter approached by the boar was nervous. |
| 102 | c | The boy-scout admitted that the hunter who was approached by the boar was nervous. |
| 102 | d | The boy-scout admitted that the hunter approached by the boar was nervous. |
| 103 | a | About a month ago the pilgrim who was touched by the pope was happy. |
| 103 | b | About a month ago the pilgrim touched by the pope was happy. |
| 103 | c | The aunt confirmed that the pilgrim who was touched by the pope was happy. |
| 103 | d | The aunt confirmed that the pilgrim touched by the pope was happy. |
| 104 | a | In the early morning the model who was spotted by the scout went home. |
| 104 | b | In the early morning the model spotted by the scout went home. |
| 104 | c | The paparazzo mentioned that the model who was spotted by the scout went home. |
| 104 | d | The paparazzo mentioned that the model spotted by the scout went home. |
| 105 | a | On Monday at work the plumber who was insulted by the busybody was angry. |
| 105 | b | On Monday at work the plumber insulted by the busybody was angry. |
| 105 | c | The tenant confirmed that the plumber who was insulted by the busybody was angry. |
| 105 | d | The tenant confirmed that the plumber insulted by the busybody was angry. |
| 106 | a | About three weeks ago the man who was visited by the daughter injured his leg. |
| 106 | b | About three weeks ago the man visited by the daughter injured his leg. |
| 106 | c | The nurse knew that the man who was visited by the daughter injured his leg. |
| 106 | d | The nurse knew that the man visited by the daughter injured his leg. |
| 107 | a | Early on Monday afternoon the man who was observed by the dentist got the molar removed. |
| 107 | b | Early on Monday afternoon the man observed by the dentist got the molar removed. |
| 107 | c | The receptionist believed that the man who was observed by the dentist got the molar removed. |
| 107 | d | The receptionist believed that the man observed by the dentist got the molar removed. |
| 108 | a | On Tuesday last week the apprentice-boy who was hit by the butcher was crying. |
| 108 | b | On Tuesday last week the apprentice-boy hit by the butcher was crying. |
| 108 | c | The father recognized that the apprentice-boy who was hit by the butcher was crying. |
| 108 | d | The father recognized that the apprentice-boy hit by the butcher was crying. |
| 109 | a | A week ago yesterday the banker who was confronted by the customer was fired. |
| 109 | b | A week ago yesterday the banker confronted by the material was fired. |
| 109 | c | The cashier saw that the banker who was confronted by the customer was fired. |
| 109 | d | The cashier saw that the banker confronted by the customer was fired. |
| 110 | a | Only twenty minutes later the accountant who was killed by the burglar was found. |
| 110 | b | Only twenty minutes later the accountant killed by the burglar was found. |
| 110 | c | The police said that the accountant who was killed by the burglar was found. |
| 110 | d | The police said that the accountant killed by the burglar was found. |
| 111 | a | For a long time the swimmer who was celebrated by the crowd was enjoying himself. |
| 111 | b | For a long time the swimmer celebrated by the crowd was enjoying himself. |
| 111 | c | The reporter noticed that the swimmer who was celebrated by the crowd was enjoying himself. |
| 111 | d | The reporter noticed that the swimmer celebrated by the crowd was enjoying himself. |
| 112 | a | At half past nine the dancer who was watched by the man got mugged. |
| 112 | b | At half past nine the dancer watched by the man got mugged. |
| 112 | c | The juror admitted that the dancer who was watched by the man got mugged. |
| 112 | d | The juror admitted that the dancer watched by the man got mugged. |
| 113 | a | For a short while the plumber who was robbed by the burglar was shocked. |
| 113 | b | For a short while the plumber who was robbed by the forearm was shocked. |
| 113 | c | The neighbour said that the plumber who was robbed by the burglar was shocked. |
| 113 | d | The neighbour said that the plumber who was robbed by the burglar was shocked. |

| 114 | a | A week ago today the waitress who was scared by the patron despised him. |
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| 114 | b | A week ago today the waitress scared by the patron despised him. |
| 114 | c | The cleaner knew that the waitress who was scared by the patron despised him. |
| 114 | d | The cleaner knew that the waitress scared by the patron despised him. |
| 115 | a | Early on Monday morning the flight-attendant who was complimented by the tourist was smiling. |
| 115 | b | Early on Monday morning the flight-attendant complimented by the tourist was smiling. |
| 115 | c | The colleague saw that the flight-attendant who was complimented by the tourist was smiling. |
| 115 | d | The colleague saw that the flight-attendant complimented by the tourist was smiling. |
| 116 | a | Yesterday in the afternoon the serviceman who was ignored by the officer was waiting patiently. |
| 116 | b | Yesterday in the afternoon the serviceman who was ignored by but officer was waiting patiently. |
| 116 | c | The general noted that the serviceman who was ignored by the officer was waiting patiently. |
| 116 | d | The general noted that the serviceman ignored by the officer was waiting patiently. |
| 117 | a | Today two weeks ago the mother who was phoned by the school was upset. |
| 117 | b | Today two weeks ago the mother phoned by the school was upset. |
| 117 | c | The teacher reported that the mother who was phoned by the school was upset. |
| 117 | d | The teacher reported that the mother phoned by the school was upset. |
| 118 | a | For a long time the diplomat who was blackmailed by the mistress refused to pay the ransom. |
| 118 | b | For a long time the diplomat blackmailed by the mistress refused to pay the ransom. |
| 118 | c | The inspector claimed that the diplomat who was blackmailed by the mistress refused to pay the ransom. |
| 118 | d | The inspector claimed that the diplomat blackmailed by the mistress refused to pay the ransom. |
| 119 | a | Almost two weeks ago the WAG who was seduced by the footballer left him. |
| 119 | b | Almost two weeks ago the WAG seduced by the footballer left him. |
| 119 | c | The newspaper claimed that the WAG who was seduced by the footballer left him. |
| 119 | d | The newspaper claimed that the WAG seduced by the footballer left him. |
| 120 | a | At the military parade the princess who was saluted by the citizens smiled shyly. |
| 120 | b | At the military parade the princess saluted by the citizens smiled shyly. |
| 120 | c | The ambassador saw that the princess who was saluted by the citizens smiled shyly. |
| 120 | d | The ambassador saw that the princess saluted by the citizens smiled shyly. |
| 121 | a | For quite a while the veteran who was thanked by the queen was proud. |
| 121 | b | For quite a while the veteran thanked by the queen was proud. |
| 121 | c | The woman noticed that the veteran who was thanked by the queen was proud. |
| 121 | d | The woman noticed that the veteran thanked by the queen was proud. |
| 122 | a | Monday afternoon last week the producer who was annoyed by the actress was furious. |
| 122 | b | Monday afternoon last week the producer annoyed by the actress was furious. |
| 122 | c | The cameraman noticed that the producer who was annoyed by the actress was furious. |
| 122 | d | The cameraman noticed that the producer annoyed by the actress was furious. |
| 123 | a | In the early afternoon the reviewer who was urged by the publisher sent an overdue response. |
| 123 | b | In the early afternoon the reviewer urged by the publisher sent an overdue response. |
| 123 | c | The editor mentioned that the reviewer who was urged by the publisher sent an overdue response. |
| 123 | d | The editor mentioned that the reviewer urged by the publisher sent an overdue response. |
| 124 | a | Late in the morning the librarian who was shushed by the visitor was surprised. |
| 124 | b | Late in the morning the librarian shushed by with visitor was surprised. |
| 124 | c | The student heard that the librarian who was shushed by the visitor was surprised. |
| 124 | d | The student heard that the librarian shushed by the visitor was surprised. |
| 125 | a | For a long time the tennis-player who was coached by the trainer was committed. |
| 125 | b | For a long time the tennis-player coached by the trainer was committed. |
| 125 | c | The manager appreciated that the tennis player who was coached by the trainer was committed. |
| 125 | d | The manager appreciated that the tennis player coached by the trainer was committed. |
| 126 | a | Yesterday two weeks ago the president who was overruled by the committee endorsed a nominee. |
| 126 | b | Yesterday two weeks ago the president overruled by the committee endorsed a nominee. |
| 126 | c | The official said that the president who was overruled by the committee endorsed a nominee. |

| 126 | d | The official said that the president overruled by the committee endorsed a nominee. |
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| 127 | a | For quite a while the Governor who was censured by the parliament was allegedly corrupt. |
| 127 | b | For quite a while the Governor censured by the parliament was allegedly corrupt. |
| 127 | c | The journalist heard that the Governor who was censured by the parliament was allegedly corrupt. |
| 127 | d | The journalist heard that the Governor censured by the parliament was allegedly corrupt. |
| 128 | a | During the award ceremony the soloist who was inspired by the composer was nervous. |
| 128 | b | During the award ceremony the soloist inspired by the composer was nervous. |
| 128 | c | The fiancée mentioned that the soloist who was inspired by the composer was nervous. |
| 128 | d | The fiancée mentioned that the soloist inspired by the composer was nervous. |
| 129 | a | On a cold day the boxer who was challenged by the champion was confident. |
| 129 | b | On a cold day the boxer who was challenged by the champion was confident. |
| 129 | c | The commentator explained that the boxer who was challenged by the champion was confident. |
| 129 | d | The commentator explained that the boxer challenged by the champion was confident. |
| 130 | a | After a healthy breakfast the nurse who was diagnosed by the physician was asleep. |
| 130 | b | After a healthy breakfast the nurse diagnosed by the physician was asleep. |
| 130 | c | The husband said that the nurse who was diagnosed by the physician was asleep. |
| 130 | d | The husband said that the nurse diagnosed by the physician was asleep. |
| 131 | a | On Sunday last week the bachelor who was charmed by the bride was drunk. |
| 131 | b | On Sunday last week the bachelor charmed by the bride was drunk. |
| 131 | c | The groom knew that the bachelor who was charmed by the bride was drunk. |
| 131 | d | The groom knew that the bachelor charmed by the bride was drunk. |
| 132 | a | On a sunny morning the clerk who was trusted by the customer was persuasive. |
| 132 | b | On a sunny morning the clerk trusted by the customer was persuasive. |
| 132 | c | The supervisor realized that the clerk who was trusted by the customer was persuasive. |
| 132 | d | The supervisor realized that the clerk trusted by the customer was persuasive. |
| 133 | a | Last night after work the product-manager who was promoted by the boss was celebrating. |
| 133 | b | Last night after work the product-manager promoted by the boss was celebrating. |
| 133 | c | The clerk assumed that the product-manager who was promoted by the boss was celebrating. |
| 133 | d | The clerk assumed that the product-manager promoted by the boss was celebrating. |
| 134 | a | On a cold afternoon the footballer's-wife who was seduced by the friend was deeply ashamed. |
| 134 | b | On a cold afternoon the footballer's-wife seduced by the friend was deeply ashamed. |
| 134 | c | The attorney repeated that the footballer's-wife who was seduced by the friend was deeply ashamed. |
| 134 | d | The attorney repeated that the footballer's-wife seduced by the friend was deeply ashamed. |
| 135 | a | Tuesday morning last week the interpreter who was tutored by the linguist seemed nervous. |
| 135 | b | Tuesday morning last week the interpreter tutored by the linguist seemed nervous. |
| 135 | c | The girl saw that the interpreter who was tutored by the linguist seemed nervous. |
| 135 | d | The girl saw that the interpreter tutored by the linguist seemed nervous. |
| 136 | a | Before the school holidays the lecturer who was frustrated by the graduate was usually mild-tempered. |
| 136 | b | Before the school holidays the lecturer frustrated by the graduate was usually mild-tempered. |
| 136 | c | The secretary said that the lecturer who was frustrated by the graduate was usually mild-tempered. |
| 136 | d | The secretary said that the lecturer frustrated by the graduate was usually mild-tempered. |
| 137 | a | Yesterday late at night the inmate who was distrusted by the warden was screaming loudly. |
| 137 | b | Yesterday late at night the inmate distrusted by the warden was screaming loudly. |
| 137 | c | The nurse heard that the inmate who was distrusted by the warden was screaming loudly. |
| 137 | d | The nurse heard that the inmate distrusted by the warden was screaming loudly. |
| 138 | a | This morning before breakfast the toddler who was tickled by the nanny was giggling. |
| 138 | b | This morning before breakfast the toddler tickled by the nanny was giggling. |
| 138 | c | The father noticed that the toddler who was tickled by the nanny was giggling. |
| 138 | d | The father noticed that the toddler tickled by the nanny was giggling. |
| 139 | a | Last night after dinner the builder who was disturbed by the janitor was flabbergasted. |
| 139 | b | Last night after dinner the builder disturbed by the janitor was flabbergasted. |
| 139 | c | The cleaner saw that the builder who was disturbed by the janitor was flabbergasted. |
| 139 | d | The cleaner saw that the builder disturbed by the janitor was flabbergasted. |
| 140 | a | Yesterday after the fight the boxer who was ridiculed by the physiotherapist was in bad shape. |

| 140 | b | Yesterday after the fight the boxer ridiculed by the physiotherapist was in bad shape. |
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| 140 | c | The coach noticed that the boxer who was ridiculed by the physiotherapist was in bad shape. |
| 140 | d | The coach noticed that the boxer ridiculed by the physiotherapist was in bad shape. |
| 141 | a | For almost three weeks the politician who was protected by the bodyguards felt safe. |
| 141 | b | For almost three weeks the politician protected by the bodyguards felt safe. |
| 141 | c | The senator explained that the politician who was protected by the bodyguards felt safe. |
| 141 | d | The senator explained that the politician protected by the bodyguards felt safe. |
| 142 | a | Since summer last year the lawyer who was requested by the celebrity was extremely expensive. |
| 142 | b | Since summer last year the lawyer requested by the celebrity was extremely expensive. |
| 142 | c | The attorney knew that the lawyer who was requested by the celebrity was extremely expensive. |
| 142 | d | The attorney knew that the lawyer requested by the celebrity was extremely expensive. |
| 143 | a | Thursday in the afternoon the tutor who was provoked by the pupil went berserk. |
| 143 | b | Thursday in the afternoon the tutor who was provoked by the pupil went berserk. |
| 143 | c | The school-inspector noticed that the tutor who was provoked by the pupil went berserk. |
| 143 | d | The school-inspector noticed that the tutor provoked by the pupil went berserk. |
| 144 | a | For a while now the electrician who was contacted by the painter was not reliable. |
| 144 | b | For a while now the electrician contacted by the painter was not reliable. |
| 144 | c | The vicar believed that the electrician who was contacted by the painter was not reliable. |
| 144 | d | The vicar believed that the electrician contacted by the painter was not reliable. |
| 145 | a | Almost a month ago the actress who was recognized by the fan received a prize. |
| 145 | b | Almost a month ago the actress who was recognized by the fan received a prize. |
| 145 | c | The producer saw that the actress who was recognized by the fan received a prize. |
| 145 | d | The producer saw that the actress recognized by the fan received a prize. |
| 146 | a | Friday at the hearing the lawyer who was confused by the barrister was too defensive. |
| 146 | b | Friday at the hearing the lawyer confused by the barrister was too defensive. |
| 146 | c | The witness thought that the lawyer who was confused by the barrister was too defensive. |
| 146 | d | The witness thought that the lawyer confused by the barrister was too defensive. |
| 147 | a | During the conference talk the scientist who was reviewed by the peer was knowledgeable. |
| 147 | b | During the conference talk the scientist reviewed by the peer was knowledgeable. |
| 147 | c | The editor believed that the scientist who was reviewed by the peer was knowledgeable. |
| 147 | d | The editor believed that the scientist reviewed by the peer was knowledgeable. |
| 148 | a | On Tuesday at midnight the spy who was alarmed by the agent was wary. |
| 148 | b | On Tuesday at midnight the spy alarmed by the agent was wary. |
| 148 | c | The investigator stated that the spy who was alarmed by the agent was wary. |
| 148 | d | The investigator stated that the spy alarmed by the agent was wary. |
| 149 | a | On Monday at lunch the visitor who was sketched by the artist was flattered. |
| 149 | b | On Monday at lunch the visitor sketched by the artist was flattered. |
| 149 | c | The woman remembered that the visitor who was sketched by the artist was flattered. |
| 149 | d | The woman remembered that the visitor sketched by the artist was flattered. |
| 150 | a | Late on Sunday afternoon the striker who was fouled by the defender complained loudly. |
| 150 | b | Late on Sunday afternoon the striker fouled by the defender complained loudly. |
| 150 | c | The referee observed that the striker who was fouled by the defender complained loudly. |
| 150 | d | The referee observed that the striker fouled by the defender complained loudly. |
| 151 | a | On a cold afternoon the victim who was identified by the witness was badly shaken. |
| 151 | b | On a cold afternoon the victim identified by the witness was badly shaken. |
| 151 | c | The detective indicated that the victim who was identified by the witness was badly shaken. |
| 151 | d | The detective indicated that the victim identified by the witness was badly shaken. |
| 152 | a | After the serious incident the politician who was manipulated by the vice president was disreputable. |
| 152 | b | After the serious incident the politician manipulated by the vice president was disreputable. |
| 152 | c | The lawyer said that the politician who was manipulated by the vice president was disreputable. |
| 152 | d | The lawyer said that the politician manipulated by the vice president was disreputable. |
| 153 | a | Tuesday night last week the boy who was patronized by his girlfriend was immensely angry. |
| 153 | b | Tuesday night last week the boy patronized by his girlfriend was immensely angry. |
| 153 | c | The mother assumed that the boy who was patronized by his girlfriend was immensely angry. |
| 153 | d | The mother assumed that the boy patronized by his girlfriend was immensely angry. |

| 154 | a | Last night at dinner the scientist who was awarded by the committee was pleasantly surprised. |
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| 154 | b | Last night at dinner the scientist awarded by the committee was pleasantly surprised. |
| 154 | c | The dean saw that the scientist who was awarded by the committee was pleasantly surprised. |
| 154 | d | The dean saw that the scientist awarded by the committee was pleasantly surprised. |
| 155 | a | On Sunday at dawn the soldiers who were ambushed by the insurgents were badly injured. |
| 155 | b | On Sunday at dawn the soldiers ambushed by the insurgents were badly injured. |
| 155 | c | The correspondent reported that the soldiers who were ambushed by the insurgents were badly injured. |
| 155 | d | The correspondent reported that the soldiers ambushed by the insurgents were badly injured. |
| 156 | a | During the last years the woman who was comforted by her sister suffered psychological problems. |
| 156 | b | During the last years the woman comforted by her sister suffered psychological problems. |
| 156 | c | The neighbour said that the woman who was comforted by her sister suffered psychological problems. |
| 156 | d | The neighbour said that the woman comforted by her sister suffered psychological problems. |
| 157 | a | After the heated argument the footballer who was displeased by the manager transferred that month. |
| 157 | b | After the heated argument the footballer displeased by the manager resigned transferred that month. |
| 157 | c | The assistant admitted that the footballer who was displeased by the manager transferred that month. |
| 157 | d | The assistant admitted that the footballer displeased by the manager transferred that month. |
| 158 | a | Wednesday two days ago the MP who was humiliated by the speaker got drunk. |
| 158 | b | Wednesday two days ago the MP humiliated by the speaker got drunk. |
| 158 | c | The lobbyist heard that the MP who was humiliated by the speaker got drunk. |
| 158 | d | The lobbyist heard that the MP humiliated by the speaker got drunk. |
| 159 | a | During the last four days the solicitor who was informed by the secretary was worried. |
| 159 | b | During the last four days the solicitor informed by the spy was worried. |
| 159 | c | The law-officer noticed that the solicitor who was informed by the spy was worried. |
| 159 | d | The law-officer noticed that the solicitor informed by the spy was worried. |
| 160 | a | Tuesday afternoon last week the man who was kidnapped by the bank-robber was petrified. |
| 160 | b | Tuesday afternoon last week the man kidnapped by the bank-robber was petrified. |
| 160 | c | The witness reported that the man who was kidnapped by the bank-robber was petrified. |
| 160 | d | The witness reported that the man kidnapped by the bank-robber was petrified. |
| 161 | a | After almost a decade the singer who was misjudged by the agent became successful. |
| 161 | b | After almost a decade the singer misjudged by the agent became successful. |
| 161 | c | The composer knew that the singer who was misjudged by the agent became successful. |
| 161 | d | The composer knew that the singer misjudged by the agent became successful. |
| 162 | a | Yesterday at the meeting the politician who was probed by the parliament was deeply offended. |
| 162 | b | Yesterday at the meeting the politician probed by the parliament was deeply offended. |
| 162 | c | The man believed that the politician who was probed by the parliament was deeply offended. |
| 162 | d | The man believed that the politician probed by the parliament was deeply offended. |
| 163 | a | After ten long years the executive who was recruited by the company was promoted. |
| 163 | b | After ten long years the executive recruited by the company was promoted. |
| 163 | c | The clerk knew that the executive who was recruited by the company was promoted. |
| 163 | d | The clerk knew that the executive recruited by the company was promoted. |
| 164 | a | Sunday morning last week the wife who was left by her husband was crying. |
| 164 | b | Sunday morning last week the wife left by her husband was crying. |
| 164 | c | The daughter knew that the wife who was left by her husband was crying. |
| 164 | d | The daughter knew that the wife left by her husband was crying. |
| 165 | a | Yesterday in the morning the doctor who was notified by the surgeon rushed to hospital. |
| 165 | b | Yesterday in the morning the doctor notified by the surgeon rushed to hospital. |
| 165 | c | The nurse believed that the doctor who was notified by the surgeon rushed to hospital. |
| 165 | d | The nurse believed that the doctor notified by the surgeon rushed to hospital. |
| 166 | a | In the late afternoon the graduate who was deceived by the experimenter was not attentive. |
| 166 | b | In the late afternoon the graduate deceived by the experimenter was not attentive. |

| 166 | c | The lecturer noticed that the graduate who was deceived by the experimenter was not attentive. |
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| 166 | d | The lecturer noticed that the graduate deceived by the experimenter was not attentive. |
| 167 | a | Yesterday late at night the bus-driver who was distracted by the passenger almost crashed. |
| 167 | b | Yesterday late at night the bus-driver distracted by the passenger almost crashed. |
| 167 | c | The girl saw that the bus-driver who was distracted by the passenger almost crashed. |
| 167 | d | The girl saw that the bus-driver distracted by the passenger almost crashed. |
| 168 | a | This morning at breakfast the journalist who was fooled by his informant was enraged. |
| 168 | b | This morning at breakfast the journalist fooled by his informant was enraged. |
| 168 | c | The editor admitted that the journalist who was fooled by his informant was enraged. |
| 168 | d | The editor admitted that the journalist fooled by his informant was enraged. |
| 169 | a | Yesterday a week ago the activist who was harassed by the policeman was shrieking. |
| 169 | b | Yesterday a week ago the activist harassed by the policeman was shrieking. |
| 169 | c | The bystander heard that the activist who was harassed by the policeman was shrieking. |
| 169 | d | The bystander heard that the activist harassed by the policeman was shrieking. |
| 170 | a | Early in the morning the racing-driver who was hindered by his teammate was disqualified. |
| 170 | b | Early in the morning the racing-driver hindered by his teammate was disqualified. |
| 170 | c | The manager confirmed that the racing-driver who was hindered by his teammate was disqualified. |
| 170 | d | The manager confirmed that the racing-driver hindered by his teammate was disqualified. |
| 171 | a | A week ago yesterday the mayor who was mocked by his opponent was blushing. |
| 171 | b | A week ago yesterday the mayor mocked by his opponent was blushing. |
| 171 | c | The photographer noticed that the mayor who was mocked by his opponent was blushing. |
| 171 | d | The photographer noticed that the mayor mocked by his opponent was blushing. |
| 172 | a | Last night before dinner the pawnbroker who was threatened by the customer was scared. |
| 172 | b | Last night before dinner the pawnbroker threatened by the customer was scared. |
| 172 | c | The mailman believed that the pawnbroker who was threatened by the customer was scared. |
| 172 | d | The mailman believed that the pawnbroker threatened by the customer was scared. |
| 173 | a | The week before last the pop star who was signed by the agent got engaged. |
| 173 | b | The week before last the pop star signed by the agent got engaged. |
| 173 | c | The composer admitted that the pop star who was signed by the agent got engaged. |
| 173 | d | The composer admitted that the pop star signed by the agent got engaged. |
| 174 | a | Since almost ten years the policeman who was ordered by the foreign minister was allergic to nuts. |
| 174 | b | Since almost ten years the policeman ordered by the foreign minister was allergic to nuts. |
| 174 | c | The sister said that the policeman who was ordered by the foreign minister was allergic to nuts. |
| 174 | d | The sister said that the policeman ordered by the foreign minister was allergic to nuts. |
| 175 | a | About three months ago the research-assistant who was supervised by the Professor came from Italy. |
| 175 | b | About three months ago the research-assistant supervised by the Professor came from Italy. |
| 175 | c | The student mentioned that the research-assistant who was supervised by the Professor came from Italy. |
| 175 | d | The student mentioned that the research-assistant supervised by the Professor came from Italy. |
| 176 | a | Only the other day the dentist who was avoided by the pensioner went to Rome. |
| 176 | b | Only the other day the dentist avoided by the pensioner went to Rome. |
| 176 | c | The receptionist heard that the dentist who was avoided by the pensioner went to Rome. |
| 176 | d | The receptionist heard that the dentist avoided by the pensioner went to Rome. |
| 177 | a | Last week on Thursday the spokesman who was quoted by the newspaper denied the reports. |
| 177 | b | Last week on Thursday the spokesman quoted by the newspaper denied the reports. |
| 177 | c | The reporter admitted that the spokesman who was quoted by the newspaper denied the reports. |
| 177 | d | The reporter admitted that the spokesman quoted by the newspaper denied the reports. |
| 178 | a | Yesterday at the restaurant the mother who was served by the busboy was drinking champagne. |
| 178 | b | Yesterday at the restaurant the mother served by the busboy was drinking champagne. |
| 178 | c | The daughter saw that the mother who was served by the busboy was drinking champagne. |
| 178 | d | The daughter saw that the mother served by the busboy was drinking champagne. |
| 179 | a | Almost three years ago the student who was interviewed by the undergraduate qualified as |

| | | engineer. |
|---|---|---|
| 179 | b | Almost three years ago the student interviewed by the undergraduate qualified as engineer. |
| 179 | c | The friend explained that the student who was interviewed by the undergraduate qualified as engineer. |
| 179 | d | The friend explained that the student interviewed by the undergraduate qualified as engineer. |
| 180 | a | Later on that day at the senior executive who was fired by the company asked for legal advice. |
| 180 | b | Later on that day the senior executive fired by the company asked for legal advice. |
| 180 | c | The wife confirmed that the senior executive who was fired by the company asked for legal advice. |
| 180 | d | The wife confirmed that the senior executive fired by the company asked for legal advice. |
| 181 | a | In the late afternoon the scout who was arrested by the detective was in a terrifying rage. |
| 181 | b | In the late afternoon the scout arrested by the detective was in a terrifying rage. |
| 181 | c | The agent warned that the scout who was arrested by the detective was in a terrifying rage. |
| 181 | d | The agent warned that the scout arrested by the detective was in a terrifying rage. |
| 182 | a | The week before last the legal assistant who was hired by the lawyer bought a new car. |
| 182 | b | The week before last the legal assistant hired by the lawyer bought a new car. |
| 182 | c | The magistrate saw that the legal assistant who was hired by the lawyer bought a new car. |
| 182 | d | The magistrate saw that the legal assistant hired by the lawyer bought a new car. |
| 183 | a | Only two days ago the curator who was instructed by the director went to Italy. |
| 183 | b | Only two days ago the curator instructed by the director went to Italy. |
| 183 | c | The archivist heard that the curator who was instructed by the director went to Italy. |
| 183 | d | The archivist heard that the curator instructed by the director went to Italy. |
| 184 | a | On Sunday before midnight the biker who was frightened by the bouncer complained to the club-owner. |
| 184 | b | On Sunday before midnight the biker frightened by the bouncer complained to the club-owner. |
| 184 | c | The girl saw that the biker who was frightened by the bouncer complained to the club-owner. |
| 184 | d | The girl saw that the biker frightened by the bouncer complained to the club-owner. |
| 185 | a | Already three hours later the cashier who was interrogated by the employer regretted the theft. |
| 185 | b | Already three hours later the cashier interrogated by the employer regretted the theft. |
| 185 | c | The salesclerk believed that the cashier who was interrogated by the employer regretted the theft. |
| 185 | d | The salesclerk believed that the cashier interrogated by the employer regretted the theft. |
| 186 | a | After almost six months the celebrity who was compensated by the newspaper was still angry. |
| 186 | b | After almost six months the celebrity compensated by the newspaper was still angry. |
| 186 | c | The director knew that the celebrity who was compensated by the newspaper was still angry. |
| 186 | d | The director knew that the celebrity compensated by the newspaper was still angry. |
| 187 | a | After the second trial the prostitute who was accused by the advocate was imprisoned immediately. |
| 187 | b | After the second trial the prostitute accused by the advocate was imprisoned immediately. |
| 187 | c | The janitor knew that the prostitute who was accused by the advocate was imprisoned immediately. |
| 187 | d | The janitor knew that the prostitute accused by the advocate was imprisoned immediately. |
| 188 | a | By early afternoon today the neurologist who was evaluated by the Professor obtained the prestigious contract. |
| 188 | b | By early afternoon today the neurologist evaluated by the Professor obtained the prestigious contract. |
| 188 | c | The nurse thought that the neurologist who was evaluated by the Professor obtained the prestigious contract. |
| 188 | d | The nurse thought that the neurologist evaluated by the Professor obtained the prestigious contract. |
| 189 | a | Within just ten minutes the ringleader who was punished by the court was released. |
| 189 | b | Within just ten minutes the ringleader punished by the court was released. |
| 189 | c | The court reporter saw that the ringleader who was punished by the court was released. |
| 189 | d | The court reporter saw that the ringleader punished by the court was released. |
| 190 | a | Later on that day the martial-artist who was taught by his father won the championship. |

| 190 | b | Later on that day the martial-artist taught by his father won the championship. |
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| 190 | c | The boy said that the martial-artist who was taught by his father won the championship. |
| 190 | d | The boy said that the martial-artist taught by his father won the championship. |
| 191 | a | By noon that day the senator who was convicted by the jury decided to resign. |
| 191 | b | By noon that day the senator convicted by the jury decided to resign. |
| 191 | c | The representative said that the senator who was convicted by the jury decided to resign. |
| 191 | d | The representative said that the senator convicted by the jury decided to resign. |
| 192 | a | Within the following year the hotelier who was graded by the inspector received an award. |
| 192 | b | Within the following year the hotelier graded by the inspector received an award. |
| 192 | c | The chef mentioned that the hotelier who was graded by the inspector received an award. |
| 192 | d | The chef mentioned that the hotelier graded by the inspector received an award. |
| 193 | a | Over two months ago the ambassador who was dismissed by the government challenged the court's-decision. |
| 193 | b | Over two months ago the ambassador dismissed by the government challenged the court's-decision. |
| 193 | c | The congressman explained that the ambassador who was dismissed by the government challenged the court's-decision. |
| 193 | d | The congressman explained that the ambassador dismissed by the government challenged the court's-decision. |
| 194 | a | Within just five years the pilot who was admired by the stewardess became proficient. |
| 194 | b | Within just five years the pilot admired by the stewardess became proficient. |
| 194 | c | The colleague admitted that the pilot who was admired by the stewardess became proficient. |
| 194 | d | The colleague admitted that the pilot who was admired by the stewardess became proficient. |
| 195 | a | At the birthday party the clown who was kicked by the boy was really frightening. |
| 195 | b | At the birthday party the clown kicked by the boy was really frightening. |
| 195 | c | The father noticed that the clown who was kicked by the boy was really frightening. |
| 195 | d | The father noticed that the clown kicked by the boy was really frightening. |
| 196 | a | Later that particular evening the congressman who was questioned by the senator became intoxicated. |
| 196 | b | Later that particular evening the congressman questioned by the senator became intoxicated. |
| 196 | c | The friend knew that the congressman who was questioned by the senator became intoxicated. |
| 196 | d | The friend knew that the congressman questioned by the senator became intoxicated. |
| 197 | a | Near dawn that day the informer who was murdered by the Mafioso failed to repay a Mafia-investment. |
| 197 | b | Near dawn that day the informer murdered by the Mafioso failed to repay a Mafia-investment. |
| 197 | c | The cop believed that the informer who was murdered by the Mafioso failed to repay a Mafia-investment. |
| 197 | d | The cop believed that the informer murdered by the Mafioso failed to repay a Mafia-investment. |
| 198 | a | During the last month the receptionist who was persuaded by her family was happy. |
| 198 | b | During the last month the receptionist persuaded by her family was happy. |
| 198 | c | The sister admitted that the receptionist who was persuaded by her family was happy. |
| 198 | d | The sister admitted that the receptionist persuaded by her family was happy. |
| 199 | a | A week ago today the criminal who was stopped by the officer was caught. |
| 199 | b | A week ago today the criminal stopped by the officer was caught. |
| 199 | c | The man reported that the criminal who was stopped by the officer was caught. |
| 199 | d | The man reported that the criminal stopped by the officer was caught. |
| 200 | a | Yesterday in the morning the window-cleaner who was instructed by his employer was careless. |
| 200 | b | Yesterday in the morning the window-cleaner instructed by his employer was careless. |
| 200 | c | The workmate said that the window-cleaner who was instructed by his employer was careless. |
| 200 | d | The workmate said that the window-cleaner instructed by his employer was careless. |
| 201 | a | On Tuesday at noon the judge who was censured by the panel admitted to injudicious conduct. |
| 201 | b | On Tuesday at noon the judge censured by the panel admitted to injudicious conduct. |
| 201 | c | The chairman knew that the judge who was censured by the panel admitted to injudicious |

| | | conduct. |
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| 201 | d | The chairman knew that the judge censured by the panel admitted to injudicious conduct. |
| 202 | a | In the past years the mayor who was represented by the barrister was accused of embezzlement. |
| 202 | b | In the past years the mayor represented by the barrister was accused of embezzlement. |
| 202 | c | The opponent proclaimed that the mayor who was represented by the barrister was accused of embezzlement. |
| 202 | d | The opponent proclaimed that the mayor represented by the barrister was accused of embezzlement. |
| 203 | a | In the early afternoon the political-refugee who was searched by the coastguards was trembling with fear. |
| 203 | b | In the early afternoon the political-refugee searched by the coastguards was trembling with fear. |
| 203 | c | The bystander realized that the political-refugee who was searched by the coastguards was trembling with fear. |
| 203 | d | The bystander realized that the political-refugee searched by the coastguards was trembling with fear. |
| 204 | a | Yesterday in the morning the officer who was examined by the specialist appeared mentally normal. |
| 204 | b | Yesterday in the morning the officer examined by the specialist appeared mentally normal. |
| 204 | c | The doctor confirmed that the officer who was examined by the specialist appeared mentally normal. |
| 204 | d | The doctor confirmed that the officer examined by the specialist appeared mentally normal. |
| 205 | a | On the cold afternoon the archaeologist who was photographed by the local-paper wore a dark suit. |
| 205 | b | On the cold afternoon the archaeologist photographed by the local-paper wore a dark suit. |
| 205 | c | The woman noticed that the archaeologist who was photographed by the local-paper wore a dark suit. |
| 205 | d | The woman noticed that the archaeologist photographed by the local-paper wore a dark suit. |
| 206 | a | After two long years the insurgent who was tortured by the interrogator was forced into exile. |
| 206 | b | After two long years the insurgent tortured by the interrogator was forced into exile. |
| 206 | c | The lawyer admitted that the insurgent who was tortured by the interrogator was forced into exile. |
| 206 | d | The lawyer admitted that the insurgent tortured by the interrogator was forced into exile. |
| 207 | a | Monday morning last week the representative who was trusted by the union had incriminated some negotiators. |
| 207 | b | Monday morning last week the representative trusted by the union had incriminated some negotiators. |
| 207 | c | The chairman saw that the representative who was trusted by the union had incriminated some negotiators. |
| 207 | d | The chairman saw that the representative trusted by the union had incriminated some negotiators. |
| 208 | a | Later on that day the manager who was promoted by the executive decided to celebrate. |
| 208 | b | Later on that day the manager promoted by the executive decided to celebrate. |
| 208 | c | The secretary believed that the manager who was promoted by the executive decided to celebrate. |
| 208 | d | The secretary believed that the manager promoted by the executive decided to celebrate. |
| 209 | a | Later that particular week the student who was seduced by her friend went to Spain. |
| 209 | b | Later that particular week the student seduced by her friend went to Spain. |
| 209 | c | The flatmate said that the student who was seduced by her friend went to Spain. |
| 209 | d | The flatmate said that the student seduced by her friend went to Spain. |
| 210 | a | On Sunday this weekend the coach who was thanked by the team embraced some runners. |
| 210 | b | On Sunday this weekend the coach thanked by the team embraced some runners. |
| 210 | c | The photographer saw that the coach who was thanked by the team embraced some runners. |
| 210 | d | The photographer saw that the coach thanked by the team embraced some runners. |
| 211 | a | Almost two days ago the journalist who was frustrated by the senator discovered illegal donations. |
| 211 | b | Almost two days ago the journalist frustrated by the senator discovered illegal donations. |
| 211 | c | The president noticed that the journalist who was frustrated by the senator had discovered illegal donations. |

| 211 | d | The president noticed that the journalist frustrated by the senator discovered illegal donations. |
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| 212 | a | In the late evening the patient who was distrusted by the nurse was recovering. |
| 212 | b | In the late evening the patient distrusted by the nurse was recovering. |
| 212 | c | The therapist thought that the patient who was distrusted by the nurse was recovering. |
| 212 | d | The therapist thought that the patient distrusted by the nurse was recovering. |
| 213 | a | Late at night today the resident who was menaced by the skinhead called the police. |
| 213 | b | Late at night today the resident menaced by the skinhead called the police. |
| 213 | c | The lawyer reported that the resident who was menaced by the skinhead called the police. |
| 213 | d | The lawyer reported that the resident menaced by the skinhead called the police. |
| 214 | a | During the lunch break the girl who was scratched by the cheerleader was flirting with her boyfriend. |
| 214 | b | During the lunch break the girl scratched by the cheerleader was flirting with her boyfriend. |
| 214 | c | The teacher believed that the girl who was scratched by the cheerleader was flirting with her boyfriend. |
| 214 | d | The teacher believed that the girl scratched by the cheerleader was flirting with her boyfriend. |
| 215 | a | Tuesday morning at school the pupil who was tickled by the friend accidentally hit him. |
| 215 | b | Tuesday morning at school the pupil tickled by the friend accidentally hit him. |
| 215 | c | The nurse said that the pupil who was tickled by the friend accidentally hit him. |
| 215 | d | The nurse said that the pupil tickled by the friend accidentally hit him. |
| 216 | a | On Monday at night the passer-by who was bullied by the thug tried to escape. |
| 216 | b | On Monday at night the passer-by bullied by the thug tried to escape. |
| 216 | c | The witness reported that the passer-by who was bullied by the thug tried to escape. |
| 216 | d | The witness reported that the passer-by bullied by the thug tried to escape. |
| 217 | a | Prior to the meeting the representative who was elected by the UN visited some ministers. |
| 217 | b | Prior to the meeting the representative elected by the UN visited some ministers. |
| 217 | c | The ambassador assumed that the representative who was elected by the UN visited some ministers. |
| 217 | d | The ambassador assumed that the representative elected by the UN visited some ministers. |
| 218 | a | In the early afternoon the researcher who was ridiculed by the supervisor was ashamed. |
| 218 | b | In the early afternoon the researcher ridiculed by the supervisor was ashamed. |
| 218 | c | The scientist knew that the researcher who was ridiculed by the supervisor was ashamed. |
| 218 | d | The scientist knew that the researcher ridiculed by the supervisor was ashamed. |
| 219 | a | Late on Saturday night the girl who was protected by the boy had provoked the bouncer. |
| 219 | b | Late on Saturday night the girl protected by the boy had provoked the bouncer. |
| 219 | c | The barman said that the girl who was protected by the boy had provoked the bouncer. |
| 219 | d | The barman said that the girl protected by the boy had provoked the bouncer. |
| 220 | a | Tuesday night last week the chef who was requested by the customer served undercooked food. |
| 220 | b | Tuesday night last week the chef requested by the customer served undercooked food. |
| 220 | c | The waitress noticed that the chef who was requested by the customer served undercooked food. |
| 220 | d | The waitress noticed that the chef requested by the customer served undercooked food. |
| 221 | a | Over two months ago the conductor who was provoked by the violinist had promoted a novice. |
| 221 | b | Over two months ago the conductor provoked by the violinist had promoted a novice. |
| 221 | c | The singer knew that the conductor who was provoked by the violinist had promoted a novice. |
| 221 | d | The singer knew that the conductor provoked by the violinist had promoted a novice. |
| 222 | a | Monday morning last week the policeman who was contacted by the man comforted a bystander. |
| 222 | b | Monday morning last week the policeman contacted by the man comforted a bystander. |
| 222 | c | The fireman noticed that the policeman who was contacted by the man comforted a bystander. |
| 222 | d | The fireman noticed that the policeman contacted by the man comforted a bystander. |
| 223 | a | Earlier on that day the chef who was terrified by the burglar had disregarded a waitress. |
| 223 | b | Earlier on that day the chef terrified by the burglar had disregarded a waitress. |
| 223 | c | The host believed that the chef who was terrified by the burglar had disregarded a waitress. |
| 223 | d | The host believed that the chef terrified by the burglar had disregarded a waitress. |
| 224 | a | Almost two weeks ago the manager who was recognized by the secretary promoted an analyst. |
| 224 | b | Almost two weeks ago the manager recognized by the secretary promoted an analyst. |

| 224 | c | The apprentice thought that the manager who was recognized by the secretary promoted an analyst. |
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| 224 | d | The apprentice thought that the manager recognized by the secretary promoted an analyst. |
| 225 | a | Early on Monday morning the Republican who was confused by the Democrat ignored many questions. |
| 225 | b | Early on Monday morning the Republican confused by the Democrat ignored many questions. |
| 225 | c | The reporter mentioned that the Republican who was confused by the Democrat ignored many questions. |
| 225 | d | The reporter mentioned that the Republican confused by the Democrat ignored many questions. |
| 226 | a | Before the important weekend the clerk who was reviewed by the manager lost his job. |
| 226 | b | Before the important weekend the clerk reviewed by the manager lost his job. |
| 226 | c | The wife knew that the clerk who was reviewed by the manager lost his job. |
| 226 | d | The wife knew that the clerk reviewed by the manager lost his job. |
| 227 | a | After the serious incident the rock-star who was liked by the girl contacted a psychiatrist. |
| 227 | b | After the serious incident the rock-star liked by the girl contacted a psychiatrist. |
| 227 | c | The receptionist mentioned that the rock-star who was liked by the girl contacted a psychiatrist. |
| 227 | d | The receptionist mentioned that the rock-star liked by the girl contacted a psychiatrist. |
| 228 | a | Almost two days ago the sheriff who was alarmed by the neighbour arrested the hooligan. |
| 228 | b | Almost two days ago the sheriff alarmed by the neighbour arrested the hooligan. |
| 228 | c | The detective explained that the sheriff who was alarmed by the neighbour arrested the hooligan. |
| 228 | d | The detective explained that the sheriff alarmed by the neighbour arrested the hooligan. |
| 229 | a | After almost ten years the woman who was sketched by the artist decided sold the picture. |
| 229 | b | After almost ten years the woman sketched by the artist decided sold the picture. |
| 229 | c | The husband believed that the woman who was sketched by the artist sold the picture. |
| 229 | d | The husband believed that the woman sketched by the artist decided sold the picture. |
| 230 | a | Last month at night the immigrant who was identified by the officer had been arrested. |
| 230 | b | Last month at night the immigrant identified by the officer had been arrested. |
| 230 | c | The deputy said that the immigrant who was identified by the officer had been arrested. |
| 230 | d | The deputy said that the immigrant identified by the officer had been arrested. |
| 231 | a | Tuesday two days ago the soldier who was patronized by the commander had defended some refugees. |
| 231 | b | Tuesday two days ago the soldier patronized by the commander had defended some refugees. |
| 231 | c | The sniper knew that the soldier who was patronized by the commander had defended some refugees. |
| 231 | d | The sniper knew that the soldier patronized by the commander had defended some refugees. |
| 232 | a | Later at the ceremony the author who was awarded by the editor disregarded a contributor. |
| 232 | b | Later at the ceremony the author awarded by the editor disregarded a contributor. |
| 232 | c | The assistant noticed that the author who was awarded by the editor disregarded a contributor. |
| 232 | d | The assistant noticed that the author awarded by the editor disregarded a contributor. |
| 233 | a | During sunset on Friday the sniper who was ambushed by the troops betrayed some confederates. |
| 233 | b | During sunset on Friday the sniper ambushed by the troops betrayed some confederates. |
| 233 | c | The investigator reported that the sniper who was ambushed by the troops betrayed some confederates. |
| 233 | d | The investigator reported that the sniper ambushed by the troops betrayed some confederates. |
| 234 | a | Before lunch on Saturday the boy who was comforted by the nanny hurt his leg. |
| 234 | b | Before lunch on Saturday the boy comforted by the nanny hurt his leg. |
| 234 | c | The girl noticed that the boy who was comforted by the nanny hurt his leg. |
| 234 | d | The girl noticed that the boy comforted by the nanny hurt his leg. |
| 235 | a | Earlier that particular day the physician who was displeased by the assistant examined some natives. |
| 235 | b | Earlier that particular day the physician displeased by the assistant examined some natives. |
| 235 | c | The nurse saw that the physician who was displeased by the assistant examined some natives. |

| 235 | d | The nurse saw that the physician displeased by the assistant examined some natives. |
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| 236 | a | On a cold afternoon the pastry-chef who was humiliated by the manager was annoyed. |
| 236 | b | On a cold afternoon the pastry-chef humiliated by the manager was annoyed. |
| 236 | c | The butler mentioned that the pastry-chef who was humiliated by the manager was annoyed. |
| 236 | d | The butler mentioned that the pastry-chef humiliated by the manager was annoyed. |
| 237 | a | Near noon that day the investigator who was informed by the FBI examined some executives. |
| 237 | b | Near noon that day the investigator informed by the FBI examined some executives. |
| 237 | c | The agent believed that the investigator who was informed by the FBI examined some executives. |
| 237 | d | The agent believed that the investigator informed by the FBI examined some executives. |
| 238 | a | Later on that day the man who was kidnapped by the hijacker was released. |
| 238 | b | Later on that day the man kidnapped by the hijacker was released. |
| 238 | c | The spokesman said that the man who was kidnapped by the hijacker was released. |
| 238 | d | The spokesman said that the man kidnapped by the hijacker was released. |
| 239 | a | A week ago today the teenager who was misjudged by the sheriff was discharged. |
| 239 | b | A week ago today the teenager misjudged by the sheriff was discharged. |
| 239 | c | The mother confirmed that the teenager who was misjudged by the sheriff was discharged. |
| 239 | d | The mother confirmed that the teenager misjudged by the sheriff was discharged. |
| 240 | a | Yesterday in the afternoon the guard who was recruited by the politician arrested some trespassers. |
| 240 | b | Yesterday in the afternoon the guard recruited by the politician arrested some trespassers. |
| 240 | c | The janitor heard that the guard who was recruited by the politician arrested some trespassers. |
| 240 | d | The janitor heard that the guard recruited by the politician arrested some trespassers. |
| 241 | a | For almost three days the boyfriend who was left by the girl was crying. |
| 241 | b | For almost three days the boyfriend left by the girl was crying. |
| 241 | c | The teacher believed that the boyfriend who was left by the girl was crying. |
| 241 | d | The teacher believed that the boyfriend left by the girl was crying. |
| 242 | a | By noon that day the tenant who was notified by the landlord was moving. |
| 242 | b | By noon that day the tenant notified by the landlord was moving. |
| 242 | c | The neighbour said that the tenant who was notified by the landlord was moving. |
| 242 | d | The neighbour said that the tenant notified by the landlord was moving. |
| 243 | a | Every day at noon the busybody who was befriended by the co-worker played golf. |
| 243 | b | Every day at noon the busybody befriended by the co-worker played golf. |
| 243 | c | The accountant noticed that the busybody who was befriended by the co-worker played golf. |
| 243 | d | The accountant noticed that the busybody befriended by the co-worker played golf. |
| 244 | a | In the following week the congressman who was deceived by the journalist was in trouble. |
| 244 | b | In the following week the congressman deceived by the journalist was in trouble. |
| 244 | c | The daughter admitted that the congressman who was deceived by the journalist was in trouble. |
| 244 | d | The daughter admitted that the congressman deceived by the journalist was in trouble. |
| 245 | a | On the warm day the housewife who was distracted by the gardener treated ate ice-cream. |
| 245 | b | On the warm day the housewife distracted by the gardener treated herself ate ice-cream. |
| 245 | c | The postman saw that the housewife who was distracted by the gardener ate ice-cream. |
| 245 | d | The postman saw that the housewife distracted by the gardener ate ice-cream. |
| 246 | a | Yesterday late at night the detective who was fooled by the doorman was surprised. |
| 246 | b | Yesterday late at night the detective fooled by the doorman was surprised. |
| 246 | c | The sergeant noticed that the detective who was fooled by the doorman was surprised. |
| 246 | d | The sergeant noticed that the detective fooled by the doorman was surprised. |
| 247 | a | For almost ten years the housekeeper who was harassed by the businessman lived in England. |
| 247 | b | For almost ten years the housekeeper harassed by the businessman lived in England. |
| 247 | c | The cleaner explained that the housekeeper who was harassed by the businessman lived in England. |
| 247 | d | The cleaner explained that the housekeeper harassed by the businessman lived in England. |
| 248 | a | About a month ago the intruder who was hindered by the policeman fled the crime-scene. |
| 248 | b | About a month ago the intruder hindered by the policeman fled the crime-scene. |
| 248 | c | The reporter said that the intruder who was hindered by the policeman fled the crime-scene. |
| 248 | d | The reporter said that the intruder hindered by the policeman fled the crime-scene. |
| 249 | a | Later in that year the schoolboy who was mocked by the teacher graduated from college. |
| 249 | b | Later in that year the schoolboy mocked by the teacher graduated from college. |

| 249 | c | The headmaster mentioned that the schoolboy who was mocked by the teacher graduated from college. |
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| 249 | d | The headmaster mentioned that the schoolboy mocked by the teacher graduated from college. |
| 250 | a | For quite a while the bridesmaid who was threatened by the bride denied flirting with the groom. |
| 250 | b | For quite a while the bridesmaid threatened by the bride denied flirting with the groom. |
| 250 | c | The vicar saw that the bridesmaid who was threatened by the bride denied flirting with the groom. |
| 250 | d | The vicar saw that the bridesmaid threatened by the bride denied flirting with the groom. |
| 251 | a | During the last decade the writer who was signed by the publisher was mostly writing novels. |
| 251 | b | During the last decade the writer signed by the publisher was mostly writing novels. |
| 251 | c | The agent explained that the writer who was signed by the publisher was mostly writing novels. |
| 251 | d | The agent explained that the writer signed by the publisher was mostly writing novels. |
| 252 | a | In the previous years the scientist who was quoted by the student published in high-impact journals. |
| 252 | b | In the previous years the scientist quoted by the student published in high-impact journals. |
| 252 | c | The editor knew that the scientist who was quoted by the student published in high-impact journals. |
| 252 | d | The editor knew that the scientist quoted by the student published in high-impact journals. |
| 253 | a | Almost six month ago the play writer who was pushed by his wife moved out. |
| 253 | b | Almost six month ago the play writer pushed by his wife moved out. |
| 253 | c | The director indicated that the play writer who was pushed by his wife moved out. |
| 253 | d | The director indicated that the play writer pushed by his wife moved out. |
| 254 | a | Today after the game the goal-keeper who was punched by the striker was placed in a police-car. |
| 254 | b | Today after the game the goal-keeper punched by the striker was placed in a police-car. |
| 254 | c | The manager admitted that the goal-keeper who was punched by the striker was placed in a police-car. |
| 254 | d | The manager admitted that the goal-keeper punched by the striker was placed in a police-car. |
| 255 | a | Already five years ago the speaker who was recorded by the psychoanalyst overcame his stammer. |
| 255 | b | Already five years ago the speaker recorded by the psychoanalyst overcame his stammer. |
| 255 | c | The daughter explained that the speaker who was recorded by the psychoanalyst overcame his stammer. |
| 255 | d | The daughter explained that the speaker recorded by the psychoanalyst overcame his stammer. |
| 256 | a | Tuesday three weeks ago the prisoner who was intimidated by his inmates spent years in jail. |
| 256 | b | Tuesday three weeks ago the prisoner intimidated by his inmates spent years in jail. |
| 256 | c | The warden mentioned that the prisoner who was intimidated by his inmates spent years in jail. |
| 256 | d | The warden mentioned that the prisoner intimidated by his inmates spent years in jail. |
| 257 | a | Yesterday two days ago the assistant who was trained by the pharmacist was considered for the position. |
| 257 | b | Yesterday two days ago the assistant trained by the pharmacist was considered for the position. |
| 257 | c | The colleague believed that the assistant who was trained by the pharmacist was considered for the position. |
| 257 | d | The colleague believed that the assistant trained by the pharmacist was considered for the position. |
| 258 | a | For quite some time the boy who was embarrassed by the father was in love with a girl. |
| 258 | b | For quite some time the boy embarrassed by the father was in love with a girl. |
| 258 | c | The mother knew that the boy who was embarrassed by the father was in love with a girl. |
| 258 | d | The mother knew that the boy embarrassed by the father was in love with a girl. |
| 259 | a | Late during last night the mayor who was elected by the citizens had received several calls. |
| 259 | b | Late during last night the mayor elected by the citizens had received several calls. |
| 259 | c | The wife explained that the mayor who was elected by the citizens had received several calls. |
| 259 | d | The wife explained that the mayor elected by the citizens had received several calls. |
| 260 | a | About a year ago the screenwriter who was rejected by the director had written some poetry. |
| 260 | b | About a year ago the screenwriter rejected by the director had written some poetry. |

| 260 | c | The actress believed that the screenwriter who was rejected by the director had written some poetry. |
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| 260 | d | The actress believed that the screenwriter rejected by the director had written some poetry. |
| 261 | a | For a long time the detective who was injured by the suspect was tracking ex-convicts. |
| 261 | b | For a long time the detective injured by the suspect was tracking ex-convicts. |
| 261 | c | The policeman assumed that the detective who was injured by the suspect was tracking ex-convicts. |
| 261 | d | The policeman assumed that the detective  injured by the suspect was tracking ex-convicts. |
| 262 | a | A week ago today the administrator who was angered by the novice got divorced. |
| 262 | b | A week ago today the administrator angered by the novice got divorced. |
| 262 | c | The accountant believed that the administrator who was angered by the novice got divorced. |
| 262 | d | The accountant believed that the administrator angered by the novice got divorced. |
| 263 | a | For almost twenty years the assistant who was respected by the boss had worked in a law-firm. |
| 263 | b | For almost twenty years the assistant respected by the boss had worked in a law-firm. |
| 263 | c | The clerk knew that the assistant who was respected by the boss had worked in a law-firm. |
| 263 | d | The clerk knew that the assistant respected by the boss had worked in a law-firm. |
| 264 | a | For quite some time the goalkeeper who was aggravated by the referee was extremely irritable. |
| 264 | b | For quite some time the goalkeeper aggravated by the referee was extremely irritable. |
| 264 | c | The teammate heard that the goalkeeper who was aggravated by the referee was extremely irritable. |
| 264 | d | The teammate heard that the goalkeeper aggravated by the referee was extremely irritable. |
| 265 | a | About five years ago the traitor who was poisoned by the spy was working for the KGB. |
| 265 | b | About five years ago the traitor poisoned by the spy was working for the KGB. |
| 265 | c | The agent reported that the traitor who was poisoned by the spy was working for the KGB. |
| 265 | d | The agent reported that the traitor poisoned by the spy was working for the KGB. |
| 266 | a | After almost thirty years the teacher who was bullied by the headmaster decided to retire early. |
| 266 | b | After almost thirty years the teacher bullied by the headmaster decided to retire early. |
| 266 | c | The tutor knew that the teacher who was bullied by the headmaster decided to retire early. |
| 266 | d | The tutor knew that the teacher bullied by the headmaster decided to retire early. |
| 267 | a | For several years now the politician who was attacked by the analyst has argued for his views. |
| 267 | b | For several years now the politician attacked by the analyst has argued for his views. |
| 267 | c | The anchor-man remembered that the politician who was attacked by the analyst has argued for his views. |
| 267 | d | The anchor-man remembered that the politician attacked by the analyst has argued for his views. |
| 268 | a | After the previous season the coach who was called by the goalkeeper made changes to the team. |
| 268 | b | After the previous season the coach called by the goalkeeper made changes to the team. |
| 268 | c | The referee heard that the coach who was called by the goalkeeper made changes to the team. |
| 268 | d | The referee heard that the coach called by the goalkeeper made changes to the team. |
| 269 | a | Early afternoon on Sunday the girl who was hugged by the clown had been crying a lot. |
| 269 | b | Early afternoon on Sunday the girl hugged by the clown had been crying a lot. |
| 269 | c | The brother believed that the girl who was hugged by the clown had been crying a lot. |
| 269 | d | The brother believed that the girl hugged by the clown had been crying a lot. |
| 270 | a | On Tuesday before noon the shoplifter who was spotted by the sleuth was stealing. |
| 270 | b | On Tuesday before moon the shoplifter spotted by the sleuth was stealing. |
| 270 | c | The shop-assistant believed that the shoplifter who was spotted by the sleuth was stealing. |
| 270 | d | The shop-assistant believed the shoplifter spotted by the sleuth was stealing. |
| 271 | a | About two days ago the accountant who was insulted by the chairman arrived at the company. |
| 271 | b | About two days ago the accountant insulted by the chairman arrived at the company. |
| 271 | c | The secretary said that the accountant who was insulted by the chairman arrived at the company. |
| 271 | d | The secretary said that the accountant insulted by the chairman arrived at the company. |
| 272 | a | Late on Saturday night the biologist who was hit by his wife was thankfully not hurt. |
| 272 | b | Late on Saturday night the biologist hit by his wife was thankfully not hurt. |
| 272 | c | The barber mentioned that the biologist who was hit by his wife was thankfully not hurt. |
| 272 | d | The barber mentioned that the biologist hit by his wife was thankfully not hurt. |

| 273 | a | During the rush hour the driver who was confronted by the woman had ignored some cyclists. |
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| 273 | b | During the rush hour the driver confronted by the woman had ignored some cyclists. |
| 273 | c | The witness reported that the driver who was confronted by the woman had ignored some cyclists. |
| 273 | d | The witness reported that the driver confronted by the woman had ignored some cyclists. |
| 274 | a | Early on Friday afternoon the guard who was killed by the smuggler was old. |
| 274 | b | Early on Friday afternoon the guard killed by the smuggler was old. |
| 274 | c | The sheriff said that the guard who was killed by the smuggler was old. |
| 274 | d | The sheriff said that the guard killed by the smuggler was old. |
| 275 | a | In the early afternoon the manager who was robbed by the burglar incriminated the bellboy. |
| 275 | b | In the early afternoon the manager robbed by the burglar incriminated the bellboy. |
| 275 | c | The maid heard that the manager who was robbed by the burglar incriminated the bellboy. |
| 275 | d | The maid heard that the manager robbed by the burglar incriminated the bellboy. |
| 276 | a | Late in the evening the pilot who was ignored by the controller was very concerned. |
| 276 | b | Late in the evening the pilot ignored by the controller was very concerned. |
| 276 | c | The investigator said that the pilot who was ignored by the controller was very concerned. |
| 276 | d | The investigator said that the pilot ignored by the controller was very concerned. |
| 277 | a | By noon that day the vet who was blackmailed by the assistant agreed to pay the ransom. |
| 277 | b | By noon that day the vet blackmailed by the assistant agreed to pay the ransom. |
| 277 | c | The wife admitted that the vet who was blackmailed by the assistant agreed to pay the ransom. |
| 277 | d | The wife admitted that the vet blackmailed by the assistant agreed to pay the ransom. |
| 278 | a | Yesterday four days ago the ambassador who was saluted by the soldiers contacted some agents. |
| 278 | b | Yesterday four days ago the ambassador saluted by the soldiers contacted some agents. |
| 278 | c | The adviser saw that the ambassador who was saluted by the soldiers contacted some agents. |
| 278 | d | The adviser saw that the ambassador saluted by the soldiers contacted some agents. |
| 279 | a | In the early morning the ranger who was thanked by the mountaineer saved him before the avalanche. |
| 279 | b | In the early morning the ranger thanked by the mountaineer saved him before the avalanche. |
| 279 | c | The pilot explained that the ranger who was thanked by the mountaineer saved him before the avalanche. |
| 279 | d | The pilot explained that the ranger thanked by the mountaineer saved him before the avalanche. |
| 280 | a | On a cold afternoon the swimmer who was shushed by the fisherman scared the fish away. |
| 280 | b | On a cold afternoon the swimmer shushed by the fisherman scared the fish away. |
| 280 | c | The sailor believed that the swimmer who was shushed by the fisherman scared the fish away. |
| 280 | d | The sailor believed that the swimmer shushed by the fisherman scared the fish away. |