Radboud Repository

Radboud University Nijmegen

PDF hosted at the Radboud Repository of the Radboud University Nijmegen

The following full text is a publisher's version.

For additional information about this publication click this link.
http://hdl.handle.net/2066/93600

Please be advised that this information was generated on 2017-12-06 and may be subject to change.

States of indecision in the brain:

Electrophysiological and hemodynamic reflections of monitoring in visual language perception

Nan van de Meerendonk

The studies described in this thesis were carried out at the Donders Institute for Brain, Cognition and Behaviour, Centre for Cognition and Centre for Cognitive Neuroimaging, at the Radboud University Nijmegen, the Netherlands.

ISBN/EAN: 978-94-91027-34-5

Cover design: Pepijn de Haan, pepijn.dehaan@gmail.com

Printed by Ipskamp Drukkers, Enschede, the Netherlands

© Nan van de Meerendonk, 2012

States of indecision in the brain:

Electrophysiological and hemodynamic reflections of monitoring in visual language perception

Proefschrift

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus prof. mr. S.C.J.J. Kortmann,
volgens besluit van het college van decanen
in het openbaar te verdedigen op dinsdag 3 juli 2012
om 15.30 uur precies
door

Nan van de Meerendonk
geboren op 7 april 1984
te Gendt

Promotoren:

Prof. dr. H.H.J. Kolk

Prof. dr. dr. P. Indefrey (Heinrich-Heine-Universität Düsseldorf, D)

Copromotoren:

Dr. D.J. Chwilla

Dr. S-A. Rueschemeyer (York University, UK)

Manuscriptcommissie:

Prof. dr. H.J. Schriefers

Dr. G.R. Kuperberg (Tufts University & Massachusetts General Hospital, USA)

Prof. dr. K.R. Ridderinkhof (Universiteit van Amsterdam)

Contents

Chapter 1

General introduction

We generally take our ability to use language to express ourselves and to understand others for granted. On a day to day basis we produce and perceive hundreds of words and combine them into meaningful sentences, both in spoken and written language. Usually, we understand what another person is saying or writing without any difficulty. Sometimes, however, this effortless understanding is interrupted and we might ask ourselves: 'Did I hear/read that correctly'? The present thesis investigates specifically these situations where comprehension is temporarily hampered, and it is proposed that a process of cognitive (or executive) control called 'monitoring' is involved in preventing these mishearings or misreadings to lead to actual misunderstandings.

Language comprehension and cognitive control

The traditional approach in language research has been to study language comprehension as if it were an encapsulated process. Language comprehension was predominantly seen as an automatic process, not influenced by other cognitive processes such as emotion, memory, and control (e.g., Fodor, 1983). However, more and more an interactive approach is taken, which assumes that various cognitive processes can influence each other. Hence, it is acknowledged that it is important to study the interaction between (at the first glance) unrelated cognitive processes to be able to understand behaviour. This change in perspective is also evident in the research field of language comprehension, where for instance the influences between emotion and language, or memory and language are now being studied (e.g., Chwilla, Virgillito, & Vissers, 2010; Nakano, Saron, & Swaab, 2009).

In the present thesis the interaction between language comprehension and a process of cognitive control called monitoring is investigated. Monitoring is a process which evaluates the demands for control and, by eliciting changes in control accordingly, assures the quality of our behaviour. A question, however, is how the brain 'knows' when adjustments in control are needed? In the action literature, where the process of monitoring has been studied quite extensively, it has been proposed that one of the ways to assess whether adjustments in control are needed is by monitoring for the presence of conflicts in information processing. Conflicts occur when there is a mismatch between what we intend or expect and what we do or observe. When such a conflict is detected, compensatory adjustments in control are triggered to resolve the problem (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001).

In language comprehension, a similar conflict monitoring mechanism has been proposed for how we deal with errors in language perception, like mishearings or misreadings, that temporarily hamper our understanding. According to the monitoring theory of language perception, which was first proposed by Kolk, Chwilla, Van Herten and Oor (2003), a conflict between an expected and an observed linguistic element – that is, a so called 'representational conflict' – can bring the language system into a state of indecision, and can trigger reprocessing of the input to check for possible processing errors. For instance, imagine that you are reading a text and you encounter the sentence: 'The man bit the dog'. Probably you will stop reading and ask yourself: 'Did I read that correctly?'. This is because the semantic content of the words in the sentence (man-bite-dog) leads us to expect that the dog is biting the man, and not the other way around. Therefore the interpretation that arises from this expectation that is based on so called 'world knowledge' (i.e., the dog bit the man), conflicts with the interpretation that arises from the sentence parse (i.e., the man bit the dog). In language perception, such a conflict could stem from two sources. Either the unexpected element (i.e., the man bit the dog) indeed occurred, or a processing error was made. Therefore, reprocessing of the input is needed, to clarify whether the initial reading was correct. The monitoring theory of language perception proposes that this monitoring process, in which a conflict between an expected and an observed linguistic element triggers reprocessing of the input, elicits a P600 effect in the electroencephalogram (EEG: see Box 1).

The monitoring theory of language perception plays a central role in the present thesis, in which we further investigated monitoring in visual language perception (i.e., written, not spoken, text). Note that, in the studies described in the present thesis, we did not investigate true perceptual errors (i.e., misreadings, like reading 'sun' as 'son'), since it would be difficult to determine when people make such errors. Instead, we simulated such errors in language perception, by embedding various types of errors in our materials. We assume that both – that is, actual misreadings and the errors in our materials – result in a similar conflict between an expected and an observed linguistic element. In this way, we simulated the consequences of errors in language perception and investigated how the language system deals with them. In the literature review in Chapter 2 we provide a thorough background of the monitoring theory of language perception. Different models that have been proposed for monitoring in the action domain and monitoring in language production will be discussed, and they will be related to the monitoring theory of language perception. Furthermore, the event-related potential (ERP: see Box 1) studies that led to the proposal of the monitoring theory of language perception will be described, followed by a discussion of the various ERP studies that were subsequently conducted to test the account. The overall picture that arises from this literature review is not that, as was generally thought, the P600 effect is driven by syntactic processes as such. Instead, and in agreement with the monitoring theory of language perception, strong expectancy violations at different levels of linguistic processing – and possibly even outside the language domain – are shown to elicit a P600 effect.

Main issues of the thesis

In the following section I will introduce the main issues that were addressed by the experimental studies conducted for the present thesis. First, in two different ERP studies, we tested whether the strength of the conflict between an expected and an observed linguistic element could influence the monitoring process (Chapter 3 and 4). Second, using functional magnetic resonance imaging (fMRI: see Box 2) we investigated the brain mechanism that is involved in monitoring for conflicts, with a specific focus on Broca's area (Chapter 4 and 5). Third, using both ERP and fMRI measurements, we investigated the possibility that, next to conflicts between an expected and observed representation, a lack of bottom-up information elicits a monitoring response as well (Chapter 5 and 6).

Manipulating conflict strength

The previous ERP studies that had been conducted to test the monitoring theory of language perception, always investigated a situation in which a conflict between an expected and an observed linguistic element was present, and compared it to a situation in which such a conflict was absent. In daily life, however, conflicts are probably not that clear-cut. On the one hand, we do sometimes encounter information

Box 1: Event-related potentials

Event-related potentials (ERPs) are electrophysiological brain responses to events in the environment. ERPs are extracted from the electroencephalogram (EEG), which is the electrical activity from the brain that can be measured by placing electrodes on the scalp. The raw EEG consists of activity from hundreds of different brain processes, which makes it difficult to identify a brain response to a specific event (e.g., a cognitive, sensory, or motor event). However, it is possible to extract these specific responses associated with certain events, that is ERPs, from the raw EEG. To extract the ERPs, small segments that are time-locked to the event of interest are cut from the EEG. By averaging a lot of these time-locked segments from the same event of interest, the electrical activity that is unrelated to the event cancels out, while the activity related to the event remains. In the ERP studies presented in this thesis, the EEG was always time-locked to the visual presentation of a critical word in a sentence: the segments that were cut from the raw EEG started 100 msec before the onset of the critical word, and lasted till 1000 msec after its onset.

The result of this averaging procedure, which is done for each participant separately, is an averaged ERP signal consisting of a sequence of positive and negative voltage peaks, so called ERP components. A common way to label these components is to refer to their polarity ('P' for positive, 'N' for negative) and latency (in msec) or ordinal position in the waveform. For instance, the first positive peak in the waveform that is generally elicited around 100 msec after presentation of a visual stimulus, is labeled the P100 (to indicate its latency) or P1 (to indicate its ordinal position). Two other characteristics that can be used to label ERP components are their distributional properties across the scalp (e.g., ELAN: Early Left Anterior Negativity) and their sensitivity to certain aspects of a task (e.g., ERN: Error Related Negativity).

One language-relevant ERP component that is of specific interest to the present thesis is the P600. The P600 is a positive-going component that generally starts around 500 msec and typically extends up to at least 800 msec after critical word onset. It usually has a central-posterior scalp distribution, and was thought to reflect syntactic processing since various syntactic anomalies and syntactically complex and ambiguous sentences elicit a more positive P600 amplitude – but see Chapter 2 for the monitoring account proposed in this thesis. Another language-relevant ERP component is the N400. The N400 is a negative-going component that peaks around 400 msec after critical word onset. The scalp distribution of the N400 is often widespread, but usually more negative over central and parietal electrode sites with a right hemisphere preponderance. In contrast to the P600, the N400 is thought to reflect semantic processing, since various semantic anomalies elicit a more negative N400 amplitude.

The ERP technique is a very valuable research tool. Although it has limited spatial resolution (i.e., the possibility to identify where in the brain cognitive processes originated), it has an excellent temporal resolution. ERPs can provide information at a millisecond time level, thereby allowing to track cognitive processes in real time.

that is highly unexpected, and to prevent the integration of false information it is useful to mistrust what we have read and check for possible processing errors. On the other hand, however, we often come across information that is a bit unexpected, for instance when reading the newspaper. Even though this information might be a bit unexpected, it can be new and important information that should be integrated to advance our learning. This suggests that not every conflict between an expected and an observed element has to result in reprocessing. If this were the case, the system would not be efficient, since we would be constantly questioning ourselves ('Did I read that correctly?'). Therefore, it was hypothesized that a conflict between competing representations should be sufficiently strong – that is, pass a certain threshold – to trigger reprocessing of the input. If this hypothesis is correct, then this might affect the ERP pattern: not every conflict should have to elicit a (similar) P600 effect.

To investigate this possibility of a 'gradation in the seriousness' of the conflict, we conducted two ERP studies in which we manipulated conflict strength. In the first study, reported in Chapter 3, we kept the expectation for a certain linguistic element the same, but we varied the degree to which the observed element violated the expectancy. To this end, participants saw sentences in which a category exemplar was highly expected, but the critical word that was actually encountered could vary in plausibility. The critical word could either be plausible, and thus in line with the expectation, or it could be mildly or deeply implausible. The following sentence is an example (the critical words are underlined, and participants either saw the plausible/mildly implausible/deeply implausible critical word):

(1) Het oog bestaande uit onder andere een pupil, iris en <u>netvlies/wenkbrauw/sticker</u> …
The eye consisting of among other things a pupil, iris and <u>retina/eyebrow/sticker</u> … (literal translation)

We predicted that, only in the case of the deeply implausible condition the conflict between the expected and the encountered linguistic element would be strong enough to trigger reprocessing and elicit a P600 effect. In the case of the mildly implausible condition, the conflict should not pass the threshold, and participants might attempt to integrate the unexpected information. To briefly summarize the results, these predictions were confirmed by the ERP patterns. While the mildly implausible condition elicited an N400 effect when compared to the plausible condition, the deeply implausible condition elicited a biphasic N400-P600 pattern. Therefore, we concluded from this study that a strong expectancy violation is needed to create a conflict that is powerful enough to trigger reprocessing.

Contrary to this study on plausibility violations, in the second ERP study in which we manipulated conflict strength (Chapter 4), the expectancy based on the sentence context was varied while the violation that occurred in the sentences was kept the same. To this end, spelling errors, specifically pseudohomophones (i.e., orthographically incorrect, but phonologically correct words) were embedded in sentences that were either weakly or strongly predictive of a certain word. For instance:

(2) De kussens zijn opgevuld met <u>verun</u> ... (strongly predictive)
The pillows are stuffed with <u>feathurs</u> … (literal translation)

(3) Op die plek liggen soms <u>verun</u> … (weakly predictive)
At that spot there sometimes lie <u>feathurs</u> ... (paraphrase)

We hypothesized that in the case of the spelling errors in strongly predictive sentences, a stronger conflict between the expected and the observed linguistic element should be triggered, since in these sentences a certain word is expected based on the sentence context and the encountered word is incorrectly spelled. The conflict for spelling errors in weakly constraining sentences should be weaker: although the word is misspelled, there is no expectation for a certain word based on the sentence context. In addition to these spelling errors, we added a condition that contained sentences with syntactic agreement violations. An example of a syntactic agreement violation is the following:

(4) De schone kleren en handdoeken <u>hangt</u> …
The clean clothes and towels <u>hangs</u> … (literal translation)

Syntactic agreement violations generally elicit a P600 effect, and therefore the ERP response to this condition and the condition containing spelling errors – which are both thought to elicit a representational conflict – could be compared as well. We expected a larger P600 for the spelling errors in the strongly predictive sentences, compared to the spelling errors in the weakly predictive sentences. In addition, we predicted this P600 effect to be similar to the P600 effect elicited by syntactic agreement violations. The results of this study indicated that both spelling errors in strongly and weakly predictive sentences elicited a P600 effect when compared to their correct counterparts (i.e., 'veren, feathers'), which was similar to the P600 effect found to syntactic agreement violations. In line with the conflict strength manipulation, the P600 effect was larger for the misspellings in the strongly predictive sentences. The fact that the spelling errors in the weakly predictive sentences also elicited a P600 effect (though smaller than in strongly predictive sentences), was taken to indicate that next to expectations based on the sentence context the word context as such can also have an effect. In conclusion, this study again showed that manipulating conflict strength, in this case by varying the expectancy for a certain word while keeping the unexpected encountered element the same, can influence the P600 effect.

Brain mechanism involved in conflict monitoring

As discussed in the previous paragraph, conflict monitoring is one of the ways to determine whether adjustments in control are needed. In the action domain, generally two brain regions are thought to play an important role in this monitoring process, namely the anterior cingulate cortex (ACC) and the prefrontal cortex (PFC). On the one hand, the ACC is thought to be important for the detection of a conflict between competing responses (e.g., Botvinick et al., 2001; Yeung, Botvinick, & Cohen, 2004). On the other hand, the PFC – which has been linked to cognitive control processes in numerous studies (for reviews see e.g., Duncan & Owen, 2000; Miller, 2000) – is thought to provide a bias signal to favour the pathways in other brain areas that are relevant for the task at hand (e.g., Miller, 2000; Miller & Cohen, 2001). In general it is assumed that by detecting the conflict the ACC signals to the PFC that adjustments in the allocation of attention are needed (e.g., Cohen, Botvinick, & Carter, 2000; Miller & Cohen, 2001).

In Chapter 4 and 5 of the present thesis we used fMRI to investigate this brain mechanism in relation to conflict monitoring in visual language perception. In particular, we focused on a portion of the PFC: the posterior part of the left inferior frontal gyrus (henceforth: lIFG). This part of the lIFG comprises Brodmann's area (BA) 44 and 45, and is also referred to as 'Broca's area' in language research. Based on the results of various sentence processing studies, activation in Broca's area has been attributed to syntactic processing. For instance, various studies have investigated syntactically ambiguous sentences, so called 'garden-path sentences', and reported increased lIFG activation (e.g., Mason, Just, Keller, & Carpenter, 2003). However, in the cognitive control literature, the lIFG has also been implicated in various tasks that do not require syntactic or language-specific processing. For instance, a classic cognitive control task, that is used to study representational conflict, is the Stroop task (Stroop, 1935). In this task, participants have to name the ink colour of a word and ignore the meaning of the printed word which also denotes a colour. In the incongruent trials, the ink colour to be named conflicts with the meaning of the printed word (e.g., *red* printed in green ink). These incongruent trials show increased lIFG activation, and it is proposed that, to overcome the prepotent response (i.e., reading the word) the lIFG implements adjustments in control to bias attention towards the task-relevant information (i.e., the ink color) (e.g., see Milham, Banich, & Barad, 2003; Nee, Wager, & Jonides, 2007; Novick, Trueswell, & Thompson-Schill, 2005). To account for these findings in the psycholinguistic and cognitive control literature, Novick et al. (2005) proposed a unifying account. According to this account, the lIFG is involved in conflict resolution in general. When a conflict between competing representations is present, the lIFG adjusts control to bias activation towards one of the representations. Therefore, to come back to the case of syntactically ambiguous sentences, a similar conflict resolution mechanism as in

Box 2: Functional Magnetic Resonance Imaging

Functional Magnetic Resonance Imaging (fMRI) is a special MRI technique used to localize cognitive processes in the brain, by measuring changes in blood flow. When the neurons in a certain brain region increase their activation, this is accompanied by an increased oxygen consumption in these neurons. Subsequently, the increased oxygen consumption causes an increased blood flow to the activated brain region. In this process, the fMRI measurement focuses on the magnetic properties of hemoglobin, a protein in the red blood cells which carries oxygen in the blood stream. Due to the increased blood flow in the neighborhood of active neurons, the proportion of oxygen-rich hemoglobin increases as well, causing changes in the magnetic properties of the blood which are reflected in the fMRI signal. Hence, by measuring this Blood-Oxygenation-Level Dependent (BOLD) signal, the neural activity that is generated by mental processes is indirectly measured.

In contrast to ERP measurements (see Box 1), fMRI has a very good spatial resolution (typically up to 2-3 mm), and is therefore an important research tool for the identification of brain regions that are involved with certain cognitive processes. Its temporal resolution, however, is poor, because the peak of the BOLD signal occurs 4-6 seconds after neuronal activity.

the Stroop task is proposed to occur. To recover from ambiguous sentences, the lIFG needs to bias attention towards the relevant encountered parse of the sentence, which conflicts with the preferred sentence parse. In support of this general conflict resolution mechanism in lIFG, January, Trueswell, and Thompson-Schill (2009) showed within the same participants that representational conflicts elicited by the Stroop task and syntactically ambiguous sentences elicited similar lIFG activation.

In the fMRI experiment in Chapter 4 we investigated the account of a general conflict resolution mechanism in lIFG with respect to errors in visual language perception. As discussed previously, the monitoring theory of language perception also assumes that errors in language perception consist of a representational conflict between an expected and an observed linguistic element. Hence, the question was whether various types of language errors would also elicit similar lIFG activation, and support the assumption of a general conflict resolution area. Therefore, we compared within the same participants the lIFG activation elicited by syntactic agreement violations with the lIFG activation elicited by spelling errors. An example of a syntactic agreement violation is given in example (4) above. For an example of the spelling errors, see example (2) and (3), which gave us the opportunity to additionally investigate whether conflict strength influences the fMRI activations. The main finding of this fMRI study was that both syntactic agreement violations and spelling errors elicited stronger activation in the lIFG compared to their correct controls. In short, this result was taken as further evidence that the lIFG is involved in general conflict resolution, and not syntactic processing as such. Furthermore, in contrast to the ERP findings, conflict strength did not affect the hemodynamic response. In the discussion of Chapter 4 and Chapter 7 these differential findings in the EEG and fMRI are discussed.

In Chapter 5 we investigated the proposal of a general conflict resolution mechanism in lIFG in relation to errors in language perception even further. The question was whether we could also find evidence – as January et al. (2009) reported for syntactically ambiguous sentences – for a generalization of conflict resolution in a cognitive control task (i.e., Stroop task) to conflict resolution for errors in language perception. Therefore, while lying in an fMRI scanner, participants read sentences that contained syntactic agreement violations (see example (4)) and sentences that contained plausibility violations (see example (1)). In addition, they performed a Stroop task, to allow us to independently localize the part of the lIFG that is active to the incongruent Stroop trials which elicit a representational conflict. We hypothesized that the proposal of lIFG involvement in implementing cognitive control to resolve representational conflicts in general would be strengthened, if activation within the same lIFG region would be found for the conflicts elicited by the Stroop task and syntactic and plausibility violations. The results indicated that this was the case: both syntactic agreement violations and violations of plausibility increased activation in the lIFG region that was selected based on the Stroop task. Hence, these findings further extended the proposal by Novick et al. (2005) that cognitive control mechanisms in the lIFG are recruited to resolve various types of representational conflict. Next to conflicts elicited by syntactic ambiguities, conflicts elicited by syntactic agreement violations and violations of plausibility show similar activation as the Stroop conflict in the lIFG.

Monitoring response to a lack of bottom-up information

In the main issues discussed so far, we addressed one of the ways in which the need for adjustments in control can be signalled, namely the presence of a strong conflict between an expected and an observed linguistic element. However, other cognitively demanding inputs might also interrupt comprehension, and signal the need for control adjustments (e.g., Botvinick et al., 2001; Duncan & Owen, 2000). In visual language perception, a good example of cognitively demanding inputs that hamper our understanding and might also require control adjustments are words that are difficult to read. Imagine, for instance, trying to read a prescription from your doctor who has very poor handwriting. To facilitate the identification of what the doctor has written down, extra attention needs to be allocated. Hence, besides conflicts between expected and observed representations, a lack of bottom-up information might also elicit a monitoring response and signal that adjustments in control are needed. In Chapter 5 and 6 we investigated this possibility. To this end, a visual degradation condition was constructed. This condition consisted of the weakly predictive sentences that were used in Chapter 4 (see example (3)). These sentences did not elicit an expectation for a certain word, and they did not – as was the case in Chapter 4 – contain an error of any kind. Instead, the critical words could now be visually degraded by randomly removing 75% of the pixels, or they were presented normally at full vision (i.e., undegraded).

In the fMRI study of Chapter 5 this visual degradation condition was added, next to the other conditions that were discussed in the previous paragraph – that is, syntactic agreement violations, plausibility violations, and the Stroop task. Again, as was the case for the other conditions, the lIFG was of specific interest to us. We hypothesized that if the visual degradation condition would show similar lIFG activation as the other conditions, this could indicate that a biasing of attention by lIFG is needed not only to resolve representational conflicts, but also to compensate for a lack of bottom-up information. The results showed that both the representational conflict conditions (i.e., syntactic agreement violations, and plausibility violations) and the visual degradation condition elicited increased activation in the lIFG region that was selected based on the Stroop task. Therefore, we concluded that the involvement of the lIFG may be extended beyond adjusting control in situations of representational conflicts (e.g., Novick et al., 2005) to situations in which control adjustments are triggered by a lack of bottom-up information.

In Chapter 6 we compared within the same participants the ERP response to two types of representational conflicts (i.e., syntactic agreement violations, and plausibility violations) with the ERP response to visual degradation. As indicated previously, the monitoring theory of language perception assumes that, in the case of representational conflicts, attention is biased towards the unexpected observed representation and therefore leads to reprocessing of the input to check for possible processing errors. This monitoring response has consistently been found to elicit a P600 effect. Therefore, our question was whether this P600 effect would generalize to the situation of visual degradation, in which control adjustments are also assumed to compensate for the lack of bottom-up information. The main finding of this chapter was that both the representational conflict conditions and the visual degradation condition elicited long-lasting positivities in the EEG, though with some variations in their timing and distribution across the scalp. Based on these results, we proposed that a general monitoring process which evaluates the demands for control could underlie these positivities. However, the type and complexity of the information that interrupts comprehension, and that needs to be reprocessed or identified, can influence the specific timings and scalp distributions of the positivities. Therefore, we concluded from this ERP study that the monitoring theory of language perception should be extended:

next to strong representational conflicts, a lack of bottom-up information can also elicit a monitoring response and give rise to a long-lasting positivity in the EEG.

A note on the structure of the thesis

In the following chapters I will elaborate on the review of the literature on the monitoring theory of language perception (Chapter 2) and the ERP and fMRI studies conducted for the present thesis (Chapter 3 to 6), which were briefly discussed in the previous sections. These chapters have been published or submitted as journal articles, and can therefore be read as independent chapters. As a consequence, however, some overlap can exists between the introduction, methods, and discussion sections of different chapters. In Chapter 7, which has not been published or submitted as an article, I will present a summary and discussion of the main findings of the present thesis on monitoring in language perception.

Chapter 2

Monitoring in language perception

This chapter has been published as:

Van de Meerendonk, N., Kolk, H.H.J., Chwilla, D.J., & Vissers, C.T.W.M. (2009). Monitoring in language perception. *Language and Linguistics Compass, 3*(5), 1211-1224.

Abstract

Monitoring is an aspect of executive control that entails the detection of errors and the triggering of corrective actions when there is a mismatch between competing responses or representations. In the language domain, research of monitoring has mainly focused on errors made during language production. However, in language perception, for example while reading or listening, errors occur as well and people are able to detect them. A hypothesis that was developed to account for these errors is the monitoring hypothesis for language perception. According to this account, when a strong expectation conflicts with what is actually observed, a reanalysis is triggered to check the input for processing errors reflected by the P600 component. In contrast to what has been commonly assumed, the P600 is thought to reflect a general reanalysis and not a syntactic reanalysis. In this review we will describe the different studies that led to this hypothesis and try to extend it beyond the language domain.

Humans adjust themselves to the circumstances they are faced with, and an important information source for these adjustments are errors. For example, an American crossing a street in England, where they drive on the opposite side of the road, may automatically but erroneously look left first. However, with more experience (e.g., an oncoming car honking) he will learn to control this automatic response and implement the correct behavior for the traffic system in England (i.e., look right first). Just as errors are important in daily life, they have an important regulating effect on cognitive processes. The process of executive control through which the quality of our behavior is assured is called ‘monitoring’. Monitoring entails the detection of errors and the triggering of corrective actions when there is a mismatch between competing responses or representations.

In this review, the focus will be on monitoring in language perception. We will first describe different models that have been proposed for monitoring as such and relate them to the monitoring hypothesis that we propose for language perception. Then we will go into the studies that led to the proposal of this hypothesis, and describe the experiments that tested the account. Furthermore, we will discuss commonalities and differences regarding the event-related potential (ERP) patterns found in these studies, and end with a possible extension of the hypothesis beyond the language domain.

Models of monitoring

In different cognitive domains, a monitoring process has been proposed. For example, in the action domain, it has been proposed that ongoing actions and outcomes are monitored and evaluated with respect to internal goals. When an error is made in a choice reaction time task, like the Eriksen flanker task (Eriksen & Eriksen, 1974), the Error Related Negativity (ERN) component is elicited in the electroencephalogram (EEG) around 100 msec after the erroneous response. The ERN is commonly thought to reflect a monitoring process that, when a mismatch is detected between the executed and correct response, signals that an error was made. To date, it is debated what actually triggers this monitoring process and which aspect of action monitoring is reflected by the ERN (for a review, see Yeung et al., 2004). Two views that are important for the present review are the mismatch theory (e.g., Coles, Scheffers, & Holroyd, 2001) and the conflict monitoring theory (e.g., Botvinick et al., 2001). In the mismatch theory the monitor is seen as a comparator that compares the executed with the correct response. When there is a mismatch, the comparator sends an error signal to a remedial action system and the ERN is generated. The remedial action system initiates actions to inhibit or correct the error, and makes strategic adjustments to reduce the likelihood for future errors (Coles et al., 2001). Holroyd and Coles (2002) extended the mismatch theory by developing the reinforcement-learning theory. According to this theory the ERN reflects a reinforcement-learning signal that is carried by the midbrain dopamine system and is transmitted to the anterior cingulate cortex (ACC). The ACC uses the reinforcement-learning signal to recognize the appropriate motor controller and optimize performance accordingly. In contrast to the mismatch theory, in the conflict monitoring theory, monitoring is not seen as a comparison process, but involves the detection of coactivated incompatible responses. After an error has been made, processing continues and the correct response is activated internally. The coactivated responses create a conflict that, when exceeding a certain threshold, is detected by the ACC. The ACC then signals other brain areas to make adjustments in control. The ERN is thought to reflect the response conflict. Therefore, according to this account, the ERN is also a sign for error detection but does not reflect the error-detection process as such (Botvinick et al., 2001).

In the language domain, it is generally accepted that monitoring takes place in production. Monitoring in production becomes apparent when we overtly repair our speech. Take for example the following overt self-repair reported by Levelt (1983):

(1) Go from left again to, uh..., from pink again to blue.

This example shows that we can detect when our utterances deviate from our intentions, and are able to correct them. According to Levelt's (1983, 1989) perceptual loop theory of self-monitoring, speakers continuously compare their intentions with the planned or produced utterance, and when there is a mismatch a repair is made. The monitor in Levelt's model therefore is hypothesized to be a central, conscious process that oversees end-products of speech production (Postma, 2000). Another model that deals with speech monitoring is the node structure theory (NST) by MacKay (1987, 1990, 1992). MacKay assumes that errors are detected automatically by the activation patterns in the node system. Take for example the utterance of *srace* instead of *space*. In the node system there is no mother node with strong connections (committed node) that represents the initial consonant cluster *sr*. Therefore, when daughter nodes *s* and *r* are activated together, an uncommitted mother node is primed that represents initial constant clusters and is weakly connected to the *s* and *r* nodes. Due to these weak connections with the daughter nodes the uncommitted node cannot be inhibited. Inhibition occurs after a node has been activated, and is needed to prevent the node to become activated again. In the case of inhibition failure, activation is prolonged, inducing awareness leading to error detection. Often, however, a phonological speech error results in a real word and not a nonword (lexical bias effect). An example is the utterance *cool tarts* instead of *tool carts*. According to the NST these errors are harder to detect, since committed nodes exist for the segments, syllables and words involved. The error could still be detected; since now no committed node exists higher up in the hierarchy, as no noun phrase (NP) node corresponding to *cool tarts* will be available (MacKay, 1992). As in the action monitoring literature, these two models of monitoring in language production are in disagreement about the interpretation of the monitoring process. Levelt's perceptual loop theory, as well as the mismatch theory by Coles et al. (2001), assumes a continuous comparator process for monitoring. In contrast, MacKay's NST, as well as the conflict theory by Botvinick et al. (2001), does not assume that such a continuous comparison process is needed to detect errors. Error detection is thought to be automatic when, due to failed inhibition, prolonged activation of a node leads to awareness.

So far, monitoring in the language domain has been exclusively studied in language production. However, in language perception, errors are made as well. For example, during a conversation we sometimes misunderstand the speaker, and experience 'slips of the ear' (Cutler & Butterfield, 1992). For example, a mishearing of guests in a restaurant who were listening to a waiter was 'Foot on the table', while he had actually produced 'Food on the table'. Besides these occasional mishearings, we also sometimes make errors while reading a text. For example, Kaufman and Obler (1995) showed that normal adult readers make various 'slips of the eye' (e.g., omissions/insertions of words/letters, parsing errors, homonym errors). These reading errors can occur at various levels, like the syntactic (reading 'posts' as a noun instead of a verb), phonological (reading 'sun' as 'son'), and semantic level (reading 'Armenians' instead of 'Americans'). How could these perceptual errors be monitored for? In language perception it is not possible, as in production, to observe the errors directly, since they do not lead to observable behavior and furthermore, the intentions of the other person are unknown. Therefore, a comparison between intentions and actual events, as is assumed in the mismatch theory (Coles et al., 2001) and the perceptual loop theory (Levelt, 1983, 1989), is not possible. However, a listener can be assumed to have expectations about what the speaker or writer could intend. Therefore, we propose that a strong conflict between expected and perceived representations can trigger a reanalysis of the input to check for processing errors, reflected by the P600 component in the EEG. Therefore, as the conflict monitoring theory proposes for action monitoring (Botvinick et al., 2001), we hypothesize that the conflict between the different representations constitutes the internal signal to detect errors of language perception. The conflict functions as a bottom-up signal, for which no comparison process is needed. Whether conflict detection in the language domain engages the same neural circuitry as proposed for the action domain (e.g., Botvinick et al., 2001) is yet unclear.

P600 effects to non-syntactic violations

The first proposal of conflict monitoring in language perception arose when different studies unexpectedly reported P600 effects to semantic violations. Until then, it had been generally accepted that semantic violations elicit only an N400 effect. The N400 is a negative-going ERP component that peaks around 400 msec after critical word onset. Its scalp distribution is widespread, but usually more negative over central and parietal electrode sites with a right hemisphere preponderance (Kutas & Van Petten, 1994). Kutas and Hillyard (1980c) discovered that the N400 was more negative in response to semantically incongruous words compared to congruous ones. Furthermore, a semantic violation was not necessary; the N400 was also found to be more negative to less expected plausible sentence endings compared to expected ones. In addition, an unexpected word that was semantically related to the expected word elicited a smaller N400 than unrelated unexpected words (Kutas & Hillyard, 1984). This amplitude difference between congruous/expected and incongruous/unexpected words is referred to as the N400 effect. One account of the N400 component is that its amplitude reflects how easily a word can be integrated into the current context (e.g., Chwilla, Hagoort, & Brown, 1998; Holcomb, 1993; Van Berkum, Hagoort, & Brown, 1999). An alternative view is the lexical access account, according to which the N400 reflects the ease with which a word can be accessed from long-term memory (e.g., Federmeier & Kutas, 1999; Kutas & Federmeier, 2000; Lau, Phillips, & Poeppel, 2008).

While the N400 is sensitive to semantic violations, the P600 was thought to be an index of syntactic processing. The P600 is a positive-going ERP component that occurs between 500 and 800 msec after critical word onset. It usually has a central-posterior scalp distribution, and was discovered by Osterhout and Holcomb (1992). An increase in P600 amplitude has been reported to various syntactic anomalies (e.g., Friederici, Pfeifer, & Hahne, 1993; Hagoort, Brown, & Groothusen, 1993; Münte, Heinze, Matzke, Wieringa, & Johannes, 1998), complex sentences (Kaan, Harris, Gibson, & Holcomb, 2000), and locally ambiguous sentences (Osterhout & Holcomb, 1992). Therefore, the P600 has been thought to reflect syntactic reanalysis or repair processes. The amplitude difference between ungrammatical or more complex/ambiguous sentences and grammatical or unambiguous sentences has been referred to as the P600 effect.

However, contrary to what was expected, Kolk et al. (2003) found a P600 effect to semantic anomalies like:

(2) De kat die voor de muizen vluchtte …

The cat that from the mice fled$_{[sg]}$ ... (literal translation)

The cat that fled$_{[sg]}$ from the mice ... (paraphrase)

Likewise, Kuperberg, Sitnikova, Caplan, and Holcomb (2003) also found a P600 effect to semantic verb-argument violations (see also, Kuperberg, Caplan, Sitnikova, Eddy, & Holcomb, 2006; Kuperberg, Kreher, Sitnikova, Caplan, & Holcomb, 2007). An example of such a violation is the following:

(3) For breakfast the eggs would only eat ...

Furthermore, Hoeks, Stowe, and Doedens (2004), and Kim and Osterhout (2005) reported a P600 effect to semantic verb-argument violations like:

(4) De speer heeft de atleten geworpen. (Hoeks et al., 2004)

The javelin has the athletes thrown. (literal translation)

The javelin has thrown the athletes. (paraphrase)

(5) The hearty meal was devouring ... (Kim & Osterhout, 2005)

Surprisingly, though all studies contained syntactically *unambiguous* sentences with semantic violations, none of them reported an N400 effect, but all reported a P600 effect. To preserve the syntactic interpretation of the P600 effect, in some of these studies it was proposed that the P600 effect reflected a reanalysis triggered by a discrepancy in the probable thematic role of the NP and the thematic role assigned by the verb (e.g., Hoeks et al., 2004; Kuperberg, Sitnikova, et al., 2003). For instance, in example (3) the inanimate subject NP (*the eggs*) violated the thematic structure of the verb (*eat*), causing an attempt to reassign the thematic role of *the eggs* from agent to theme.

Another account that tried to reconcile the P600 effect to semantic anomalies with the syntactic interpretation of the P600 was the syntactic prediction hypothesis (Kim & Osterhout, 2005; Van Herten, Kolk, & Chwilla, 2005). According to this hypothesis it is not the role reassignment as such, but the mismatch between a predicted and observed number inflection on the verb that triggers the P600 effect. The prediction for a certain inflection arises because of a strong semantic relationship between the verb and its preceding argument. Due to this 'semantic attraction' the role assignment signalled by these semantic cues is thought to be pursued (e.g., in example (5), *meal* is assigned a theme role instead of agent) eliciting an expectation for a certain inflection on the verb (-*ed* instead of –*ing*). The sentences that were used in the Kolk et al. (2003) study also contained such mismatches. Take example (2), based on general world knowledge this sentence should be interpreted as if the mice were fleeing from the cat. Therefore, a plural inflection is expected, however, a singular inflection is encountered. To test whether this mismatch elicited the P600 effect, Van Herten et al. (2005) added sentences in which the subject and object had the same number, e.g.:

(6) De kat die voor de muis vluchtte …

The cat that from the mouse fled$_{[sg]}$ ... (literal translation)

The cat that fled$_{[sg]}$ from the mouse ... (paraphrase)

If the syntactic prediction hypothesis was correct, only the sentences in which the subject and object had a different number should elicit a P600 effect. However, the results showed that, independent of the presence of a mismatch, a P600 effect was elicited, thereby ruling out the syntactic prediction hypothesis.

Kolk et al. (2003) put forward a different interpretation to explain the P600 effects to semantic violations. They introduced the monitoring hypothesis that was mentioned in the beginning: a strong conflict between representations triggers reanalysis to check for possible processing errors. The competing representations in the Kolk et al. (2003) study were elicited on the one hand by a plausibility heuristic, which combines the individual word meanings related to general world knowledge (mice flee from cats). On the other hand the syntactic parser generates an outcome (cat flees from mice). Therefore, just as the semantic attraction interpretation, the plausibility heuristic is based on the semantic relations between the words, which are combined into a mental model of the conceptual representation. However, according to the monitoring hypothesis, the P600 does not reflect a syntactic reanalysis, but has a more general function.

Vissers, Chwilla and Kolk (2007) tested whether the P600 effects in the Kolk et al. (2003) and Van Herten et al. (2005) studies were indeed elicited due to a conflict between the representations resulting from the plausibility heuristic and the parser. To this end, they replicated the Kolk et al. (2003) study. However, the participants were now instructed to direct their attention to the syntactic structure of the sentences. This was done by informing the participants that semantic reversal anomalies would be present in the experiment, and that they should not be deceived but focus on the sentence structure as such. If the P600 reflects a reanalysis triggered by a conflict, the P600 effect should now be diminished or absent due to a reduced conflict because anomalies were expected. The results of this study indeed showed a significant reduction in the P600 effect.

In addition, Van Herten, Chwilla, and Kolk (2006) showed that, to create a conflict between representations, it is not necessary for the whole sentence to be interpreted as plausible. In the first experiment of this study (Van Herten et al., 2006) and in a previous study (Van Herten et al., 2005) a biphasic N400-P600 pattern was observed to semantically implausible nonreversal sentences to which an N400 effect was expected, like:

(7) De koning die van de baby <u>beviel</u> …
The king who to the baby <u>gave birth</u> … (literal translation)
The king who <u>gave birth to</u> the baby … (paraphrase)

The materials were investigated and it was found that about half of the sentences contained plausible sentence parts forming meaningful units (e.g., giving birth to a baby). The authors hypothesized that a conflict can also arise between a plausible unit and the implausible sentence interpretation resulting from the parser. This hypothesis was tested by creating sentences that either contained a plausible or implausible unit. For example:

(8) Jan zag dat de boeren de eieren legden/maalden … (plausible/implausible unit)
John saw that the farmers the eggs laid/crushed … (literal translation)
John saw that the farmers laid/crushed the eggs … (paraphrase)

Indeed, the sentences containing a plausible unit elicited a monophasic P600, while the sentences containing an implausible unit elicited an N400 effect and a greatly reduced P600. In general, this study shows that implausibility in itself is not necessary to elicit a P600; a plausible unit in an implausible sentence can also trigger a conflict and elicit a P600.

The studies described so far are all instances in which the conflict is assumed to be at the sentence level. To investigate whether competing representations at other linguistic levels would also trigger a conflict and elicit a P600 effect, two further experiments were conducted. In the first one, Vissers, Chwilla, and Kolk (2006) created high- and low-cloze sentences in which they embedded pseudohomophones (i.e., misspellings of a word but with similar phonology):

(9) De kussens zijn opgevuld met verun ... (high-cloze)
The pillows are stuffed with feathurs … (literal translation)

(10) Haar walkman deed het niet meer vanwege de verun ...(low-cloze)
Her walkman did not work anymore because of the feathurs … (literal translation)

It was hypothesized that, only for the high-cloze sentences, there would be a strong inclination to accept the pseudohomophone because of its similar phonology and orthography with respect to the expected word (veren–feathers). However, there would also be a strong inclination to reject it because it was misspelled, hereby creating a conflict at the word level and triggering the P600 effect. When comparing these sentences to their correct counterparts, the results indeed revealed a P600 effect only for the high-cloze sentences[1,2].

[1] The low-cloze pseudohomophones seemed to elicit a reversed P600 pattern. However, closer inspection suggested that this was due to a biphasic N400-P600 pattern in the low-cloze correct word condition (see Vissers et al., 2006).

In a second experiment, a conflict was created at the conceptual level (Vissers, Kolk, Van de Meerendonk, & Chwilla, 2008). Participants were shown pictures depicting locative relationships, followed by a sentence that could describe the picture correctly or incorrectly, depending on the preposition that was used. Two types of mismatches were created; intra- and extra-dimensional mismatches. For the intra-dimensional mismatches, the opposite preposition from the same dimension (i.e., horizontal/vertical) compared to the correct preposition was used (e.g., *in front of* instead of *behind*)[3]:

(11) □○ De cirkel staat voor het vierkant. (intra-dimensional mismatch)
The circle is in front of the square. (literal translation)

For the extra-dimensional mismatches, a preposition from the other dimension was used (e.g., *above* instead of *behind*):

(12) □○ De cirkel staat boven het vierkant. (extra-dimensional mismatch)
The circle is above the square. (literal translation)

The extra-dimensional mismatches were added as a pure semantic violation to assure that, if a P600 effect would be found, this could not be explained by role reassignment. The intra-dimensional mismatches could in principle be repaired by switching the roles of the NPs. However, for the extra-dimensional mismatches this would not result in the correct sentence. The authors hypothesized that, in case of a picture-sentence mismatch, a conflict at the conceptual level would be present between the picture representation and the sentence representation. Both the intra- and extra-dimensional mismatches elicited a P600 effect, indicating that besides conflicts at the sentence and word level, conflicts at the conceptual level can trigger reprocessing as well. In addition, the fact that both mismatches elicited a P600 effect ruled out that thematic role reassignment is critical for triggering the P600 effect.

Until now, we have discussed various studies that compared sentences in which conflicts were either present or not. However, in daily conversation and while reading, we often encounter information that is a bit unexpected. This information however, can

---

[2] Gunter, Friederici and Schriefers (2000) also found that P600 amplitude could be modulated by semantic expectancy. They reported a P600 effect to article-noun gender agreement violations for high-cloze nouns but not for low cloze nouns.

[3] Before the start of the experiment, subjects were shown three example pictures, and the correct descriptions in terms of 'in front of'-'behind' and 'above'-'below' were explained.

be new and important, and should be integrated, otherwise learning is prohibited. On the other hand, we sometimes come across information that is highly unexpected and impossible to integrate in the current context. In this case, to prevent the integration of false information, it would be useful to mistrust what we heard or read and check for possible processing errors. These examples suggest that a gradation in the seriousness of a conflict exists. Therefore, in a recent study (Van de Meerendonk, Kolk, Vissers, & Chwilla, 2010; see also Chapter 3 of this thesis) the strength of the conflict was varied by manipulating the plausibility of the sentences (plausible, mildly implausible, deeply implausible). Differences in the degree of the expectancy violations were created, while keeping the expectancy based on the sentence context the same. An example:

(13) Lichaamsdelen zoals een arm, nek en teen … (plausible)
Parts of the body like an arm, neck and toe … (literal translation)

(14) Lichaamsdelen zoals een arm, nek en haar … (mildly implausible)
Parts of the body like an arm, neck and hair … (literal translation)

(15) Lichaamsdelen zoals een arm, nek en telescoop … (deeply implausible)
Parts of the body like an arm, neck and telescope … (literal translation)

It was predicted that, only the deeply implausible sentences would create a strong enough conflict to trigger reanalysis and therefore elicit a P600 effect. For the mildly implausible sentences, the conflict would not be strong enough and integration difficulties should be resolved successfully. The results confirmed these predictions. The mildly implausible sentences elicited an N400 effect when compared to the plausible sentences, while the deeply implausible sentences showed a biphasic N400-P600 pattern. This study showed that, a strong violation of expectancy is needed to create a conflict that is powerful enough to elicit a reanalysis. The existence of a threshold that has to be passed for monitoring to occur serves a clear function: efficiency. If mild conflicts would also elicit a monitoring response we would be constantly doubting ourselves ("Did I read/hear that correctly?"), and the integration of new information would be prohibited.

To summarize, a commonality for these different studies is that, in all of them a certain linguistic event is highly expected but another event is encountered. According to the monitoring hypothesis of language perception, a conflict arises between these representations and a reanalysis is triggered to check the input for processing errors.

The P600 amplitude modulation is proposed to reflect this reanalysis. This account could also explain the P600 effects found to syntactic violations and ambiguous sentences, in which a conflict between expectancies arises as well. As to syntactic violations, speech errors are a rare event – less than 1% of our utterances – so the expectation for a sentence to contain a grammatical morpheme is very strong. Furthermore, for more complex sentences, because they are more difficult, the chance of conflicting representations is higher and this may give rise to the P600 effect (Van Herten et al., 2006). It is hypothesized that, in the reanalysis, all aspects of the input are taken into account; the semantic, syntactic, orthographic, as well as phonological aspects. We hypothesize that, as a result of the reanalysis, it becomes clear that no processing error occurred and the perceived error was indeed present[4]. In addition, we assume that depending on the type of error, the reanalysis can be focused on certain aspects of the stimulus (e.g., phonological/orthographic aspects for misspellings (Vissers et al., 2006)). This might explain the fact that in the misspelling study (Vissers et al., 2006) and the picture-sentence mismatch study (Vissers et al., 2008), instead of the generally reported central-posterior scalp distribution, the P600 effect extended to some anterior sites. The type of information that is the focus of the reanalysis could give rise to variations in scalp distribution. However, to be sure, future studies should directly compare the different kinds of violations within the same group of subjects.

Monophasic vs. biphasic patterns

According to the monitoring hypothesis, a strong conflict should elicit a P600 effect. However, some of the studies that were described reported a monophasic P600 effect (e.g., Hoeks et al., 2004; Kim & Osterhout, 2005; Kolk et al., 2003; Kuperberg et al., 2007; Kuperberg, Sitnikova, et al., 2003; Van Herten et al., 2006; Van Herten et al., 2005; Vissers et al., 2006), while others reported a biphasic N400-P600 pattern (e.g., Van de Meerendonk et al., 2010; Vissers et al., 2008). This apparent discrepancy in results could be explained by the fact that in most of the studies that reported a monophasic P600 effect, the individual words could be combined to form a meaningful sentence.

[4] The various studies discussed in this review are related to the detection and recovery from language errors. However, as indicated in the beginning, adjustments are also important to prevent future errors. Experiments that show these adjustments in the language domain have yet to be performed.

However, for the deeply implausible sentences in the Van de Meerendonk et al. (2010) study, this was not possible, causing integration difficulties and eliciting an N400 effect when comparing these sentences to their plausible counterparts. In addition, in the picture-sentence mismatch study (Vissers et al., 2008) an early negativity (between 200 and 400 msec) preceded the P600 effect to the mismatching conditions. It was proposed that this early ERP effect could reflect an early N400 effect elicited by a strong semantic expectancy created by the picture.

Furthermore, contrary to what the monitoring hypothesis proposes, studies including 'strong' semantic violations have all found an N400 effect, but the results are inconsistent regarding the P600 effect. Let's take the following sentence from Kutas and Hillyard (1980c):

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

It would seem that, in this sentence a strong conflict arises between the word 'butter' and 'socks', but no P600 effect was reported. Various studies that contained strong semantic violations, however, did report a positivity following the N400 effect. For example, Ford et al. (1996) and Woodward, Ford, and Hammet (1993) presented a subset of the semantically congruous and incongruous sentences that were used in various studies by Kutas and Hillyard (1980a, 1980b, 1980c). They found that the N400 to incongruous sentence completions was accompanied by a late positivity. Gunter, Jackson, and Mulder (1992) and Swick, Kutas, and Knight (1998) found a positivity following the N400 effect to incongruous sentence endings as well.

Inconsistencies regarding the presence or absence of a concomitant P600 effect to semantic violations have also been shown to critical words in intermediate positions. Kolk et al. (2003) found that in the presence of a plausibility judgment task, a P600 effect followed the N400 effect to strong semantic violations. This effect disappeared when no judgment was required. However, in a later study by Van Herten et al. (2005) the same stimuli were found to elicit a biphasic pattern, while no judgment was asked.

Van Petten and Luka (2006) note that little research has been done to try and determine what factors influence when a monophasic N400 effect or a biphasic pattern will occur. Van de Meerendonk et al. (2010) obtained a biphasic N400-P600 pattern to critical words in intermediate sentence positions. This study showed that plausibility could be one of the factors to discriminate the different patterns. However, the sentence types and/or individual processing strategies for example, could play a role as well. Another factor that could influence the results is overlap between the N400 and P600 component (see e.g., Schwartz, Kutas, Butters, Paulsen, & Salmon, 1996), though this is hard (if not impossible) to prove. It is clear that further research is needed to clarify the commonalities and differences between the monophasic N400, biphasic N400-P600, and monophasic P600 patterns.

Functional significance of the P600 component

As discussed in this review, the view that the P600 effect is elicited exclusively by syntactic violations is no longer legitimate. As the presented ERP data show, in addition to syntactic violations, several semantic violations, orthographic violations and picture-sentence mismatches have been found to elicit a P600 effect as well. In addition, earlier studies have reported P600 effects outside the language domain. For example, Patel, Gibson, Ratner, Besson, and Holcomb (1998) found a positivity to musical violations (out-of-key chords), that was similar in scalp distribution, latency, and amplitude to the P600 effect elicited by syntactic violations. Furthermore, violations of non-linguistic abstract structures (e.g. ABCBAC and DEFEDF have a different serial structure but they share the same abstract structure 123213; GHIGHI would violate this structure) have also been found to elicit a positivity similar to the P600 effect (Lelekov-Boissard & Dominey, 2002). In addition, Núñez-Peña and Honrubia-Serrano (2004) showed that violations of arithmetic rules (e.g., 4-7-10-13-16-19-**23**) elicit a P600 effect. From these studies it is concluded by Nuñez-Peña and Honrubia-Serrano (2004) that the P600 does not necessarily reflect the violation of a linguistic rule, but that it is a more general index of violations in rule-governed sequences.

How can these various findings be accounted for? One proposal is the account of Kuperberg (2007). She proposes a linguistic explanation of the P600 effect evoked by semantic verb-argument violations. As mentioned in the beginning, Kuperberg et al. (2003) initially proposed that reassignment of thematic roles might underlie the P600 effect. However, when dividing the sentences into whether they would lend themselves to such a reassignment (determined by a plausibility judgment task on passivized versions of the sentences), Kuperberg et al. (2006) found that thematic role reassignment could not be the only trigger for the P600 effect, since the sentences that were not repairable also elicited a P600 effect (see also Kuperberg et al., 2007). In her recent review, Kuperberg (2007) describes different factors that can influence the P600 effect to semantic violations. These factors are: the semantic association between verbs and arguments, verb-based restrictions, animacy, implausibility of the final representation, context, and the experimental task. She concludes that though all these factors can influence the P600, they are not all necessary at the same time to invoke an amplitude modulation. Kuperberg (2007) proposes that there are at least two neural routes towards language comprehension. The first stream is based primarily on semantic memory, and influences the N400 component. To make predictions about upcoming words, the evolving representation of meaning (the context) is compared with patterns of relationships that are prestored within semantic memory. The second stream is a combinatorial stream that integrates an incoming word with the context, assigning thematic roles based on multiple rule-like constraints (including morphosyntactic and semantic-thematic constraints), to build up a propositional meaning. This updated context is then again compared with information within semantic memory, determining whether it is (im)plausible, and a new cycle begins (Kuperberg, 2009). The P600 effect is thought to reflect a continued (re)analysis of the combinatorial stream triggered by a conflict between the outputs of the two processing streams. The outputs conflict when, for example, the semantic memory-based stream comes up with a possible prediction, but the combinatorial stream yields an anomalous or very implausible interpretation.

The focus of Kuperberg’s account is on semantic verb-argument violations, but she leaves open the question of how P600 effects to other violations (e.g., orthographic violations) can be accounted for. A possibility could be that, as Nuñez-Peña and Honrubia-Serrano (2004) proposed, the P600 reflects a general index of rule violations. Sitnikova, Holcomb, Kiyonaga and Kuperberg (2008) reported a late positivity to unexpected action sequences in videoclips (e.g. someone who tries to shave with a rolling pin). This positivity was proposed to reflect a similar process as the continued analysis of the combinatorial stream in the language domain. The unexpected action sequences violated implicit rules, and to make sense of the event people tried to relate the central action to the objects and people around it.

A second account that could explain the various findings is the monitoring hypothesis discussed in this review. The monitoring account is similar to Kuperberg's account in that both assume that a *conflict* between representations (of which one is based on predictions) triggers a process of continued (re)analysis, reflected by the P600 component. However, a difference between the accounts is that instead of giving a linguistic explanation, in the monitoring account the P600 effects are explained in terms of error monitoring, which is an aspect of executive control. The monitoring hypothesis is therefore able to account for other kinds of violations, besides verb-argument violations, that have been shown to elicit a P600 effect. We think that a strong violation of expectancy and not a rule violation as such is the trigger for the P600 effect. Rules, however, can be imposed on stimuli and create certain expectations. Therefore, when for example grammatical or arithmetic rules are violated, there is also a strong expectancy violation.

Conclusion

Originally the P600 effect was found to be elicited by syntactic violations. However, recently the effect has been found to several other linguistic violations, and in addition a similar positive effect has been reported outside the language domain. Therefore, the empirical generalisation seems to be that the P600 effect is not driven by syntactic processes, but due to a strong expectancy violation at different levels of cognitive processing. The monitoring theory of language perception is consistent with this generalisation and proposes that strong violations can trigger a conflict, resulting in a reanalysis of the input to check for processing errors, reflected by the P600 component. This indicates that, contrary to what is commonly assumed, language perception is not purely an automatic process, but is in need of executive control. This process of control is not always active but only becomes so when bottom-up information signals the presence of a conflict.

Chapter 3

Monitoring in language perception: Mild and strong conflicts elicit different ERP patterns

This chapter has been published as:

Van de Meerendonk, N., Kolk, H.H.J., Vissers, C.T.W.M., & Chwilla, D.J. (2010). Monitoring in language perception: Mild and strong conflicts elicit different ERP patterns. *Journal of Cognitive Neuroscience, 22*(1), 67-82.

Abstract

In the language domain, most studies of error monitoring have been devoted to language production. However, in language perception, errors are made as well and we are able to detect them. According to the monitoring theory of language perception, a strong conflict between what is expected and what is observed triggers reanalysis to check for possible perceptual errors, a process reflected by the P600. This is at variance with the dominant view that the P600 reflects syntactic reanalysis or repair, after syntactic violations or ambiguity. In the present study, the prediction of the monitoring theory of language perception was tested, that only a strong conflict between expectancies triggers reanalysis to check for possible perceptual errors, reflected by the P600. Therefore, we manipulated plausibility, and hypothesized that when a critical noun is mildly implausible in the given sentence (e.g., '*The eye consisting of among other things a pupil, iris and eyebrow ...*'), a mild conflict arises between the expected and unexpected event; integration difficulties arise due to the unexpectedness but they are resolved successfully, thereby eliciting an N400 effect. When the noun is deeply implausible however (e.g., '*The eye consisting of among other things a pupil, iris and sticker ...*'), a strong conflict arises; integration fails and reanalysis is triggered, eliciting a P600 effect. Our hypothesis was confirmed; only when the conflict between the expected and unexpected event is strong enough, reanalysis is triggered.

Introduction

Monitoring refers to the process of watching over the quality of ones behavior (e.g., McGuire, Silbersweig, & Frith, 1996; Stuss & Benson, 1986). Monitoring is an aspect of executive control, which is a process that becomes necessary when different responses compete to be selected in a certain situation (e.g., Gazzaniga, Ivry, & Mangun, 2002). Monitoring entails the triggering of corrective actions whenever there is a conflict between what is planned and what is observed.

An example of the effect of monitoring in the language domain can be seen in the case of speech errors. When people produce a speech error this often leads to overt self-repairs, like: '*Go from left again to uh..., from pink again to blue*' (Levelt, 1983). This example shows that we are able to detect the discrepancy, in this case between the speech element that we intended to produce and the actual speech element that was produced, and are able to correct for our mistake. According to Levelt (1983), self-monitoring has two important functions: first, to match the intended and produced message, and second, to create instructions to adjust the message.

Many studies of monitoring in the language domain have been devoted to language production. However, in language perception, errors are made as well and we are able to detect them. Cutler and Butterfield (1992) call these perception errors 'slips of the ear'. For example, a speaker may produce '*Into opposing camps*', which the listener may erroneously perceive as '*Into a posing camp*'. Cutler and Butterfield (1992) looked at these errors in the light of how language (in particular the English language) is perceived and misperceived, but the question remains of how these errors are detected. To the best of our knowledge, perception errors have been documented, but there has been no research on how these errors are monitored for. Since the listener does not know the intentions of the speaker, perception errors cannot be observed directly by comparing the intended with the produced message. How is it then that perceptual errors are detected? In the upcoming paragraphs we will describe different studies that led to the following proposal: a strong conflict between what is expected in the current context and what is perceived triggers reanalysis of the input to check for possible processing errors. This monitoring process is reflected in a P600 effect. In order to explain how this hypothesis was developed, a brief summary of the recent ERP literature is in order.

In the language research field there used to be a clear distinction between two Event-Related Potential (ERP) components. On the one hand there was the N400 component, reflecting semantic processes. The N400 is a negative-going component that peaks around 400 msec after critical stimulus onset. The scalp distribution of the N400 is widespread but usually larger over central and parietal electrode sites with a right hemisphere preponderance (Kutas & Van Petten, 1994). It was first discovered by Kutas and Hillyard (1980c), who found that the N400 was more negative in response to words that were semantically incongruous. For example, in the sentence '*He spread the warm bread with socks*', the word *socks* elicited a larger N400 amplitude than the word *butter* in the same sentence. This difference in amplitude between congruous and incongruous words regarding their previous context has been referred to as the N400 effect. Generally, the N400 component is assumed to reflect semantic processing, more specifically, its amplitude reflects how easily a word can be integrated in the current context (e.g., Chwilla et al., 1998; Holcomb, 1993; Van Berkum et al., 1999). On the other hand there was the P600 component, reflecting syntactic processes. This is a positive component starting at about 500 msec and generally lasting till at least 800 msec after critical stimulus onset. It usually has a central-posterior scalp distribution and was first discovered by Osterhout and Holcomb (1992) who found a P600 after a syntactic anomaly. The P600 has been related to syntactic reanalysis or repair processes. Different kinds of syntactic violations, such as violations of case inflection (Münte et al., 1998), verb-noun number agreement violations (Hagoort et al., 1993), phrase structure violations (Hagoort et al., 1993) and verb inflection violations (Friederici et al., 1993) induce an increase in P600 amplitude. Syntactic complexity also has an influence on the P600 component. Kaan, Harris, Gibson and Holcomb (2000) found a P600 effect to unambiguous, syntactically correct sentences that had a relatively complex structure as compared to control sentences. Furthermore, garden-path sentences, which are sentences that are locally ambiguous and have a preferred parse (e.g. '*The broker persuaded to sell the stock ...*'), show an increase in P600 amplitude as well (Osterhout & Holcomb, 1992). This difference in amplitude between ungrammatical or more complex/garden-path sentences and grammatical or unambiguous sentences has been referred to as the P600 effect.

This clear distinction between semantic processes reflected by the N400 component and syntactic processes reflected by the P600 component, however, was challenged when different studies found P600 effects without N400 effects to semantic anomalies. Kim and Osterhout (2005) found a P600 effect to semantic verb-argument violations in sentences like '*The hearty meal was devouring*' (see also, Hoeks et al., 2004). In these sentences syntactic cues signal that *meal* is the agent of *devouring*, but the meaning of the individual words signals that *meal* is the theme of *devouring*. According to the authors, the relation between the individual words is so strong that the role assignment signalled by semantic cues is pursued and overrules the role assignment signalled by syntactic cues. Due to this so-called 'semantic attraction' between the individual words, participants perceive the grammatical correct sentence as ungrammatical (*devouring* instead of *devoured*), causing the P600 effect. Kuperberg, Sitnikova, Caplan, and Holcomb (2003) also found a P600 effect to semantic verb-argument violations in which the subject inanimate noun phrase (NP) could have had a more plausible alternative thematic role. An example sentence of such a thematic role animacy violation is the following: '*For breakfast the eggs would only eat toast and jam*'. In this example the verb *eat* elicited a P600 effect. The authors proposed that the inanimate subject NP (*the eggs*) violated the thematic structure of the verb (*eat*), causing an attempt to reassign the thematic role of the subject NP from agent to theme, thereby eliciting a P600 effect. However, this view of reassignment of thematic roles causing the P600 effect in semantic anomalies is not without problems. Why would reassignment take place in sentences that are syntactically unambiguous? The sentences allow only one interpretation or role assignment and when trying to reassign thematic roles this veridical sentence interpretation is lost (e.g., Kolk & Chwilla, 2007; Van Herten et al., 2006).[5]

Kolk et al. (2003) found a P600 effect to semantic reversal anomalies like: '*De kat die voor de muizen vluchtte rende door de kamer*' (literal translation: 'The cat that from the mice fled$_{[sg]}$ ran through the room'). These sentences did not involve verb-argument

[5] Recently, Kuperberg and colleagues have extended their view and put more emphasis on integration costs and factors determining the likelihood that an anomaly will be detected (e.g., Kuperberg, 2007; Kuperberg et al., 2006). Specifically, in her recent review, Kuperberg (2007) proposes a language comprehension system with at least two interacting processing streams (see below for a discussion of her view vs. the monitoring view).

violations, as in the Kim and Osterhout (2005) and in the Kuperberg et al. (2003) studies, since both cats and mice can flee. However, what is violated is general world knowledge; mice flee from cats and not the other way around. Van Herten et al. (2005) tested whether the P600 effect for these semantic reversal anomalies was caused by a mismatch between the observed and predicted number inflection on the verb. Based on general world knowledge, the sentence could be interpreted as if the mice were fleeing from the cat. In this case the verb should carry a plural inflection, but the perceived singular inflection of the verb violates this expectation. However, this syntactic prediction hypothesis was ruled out when it turned out that a P600 effect was also present when subject and object NP had the same number (e.g., '*De kat die voor de muis vluchtte* ...', literal translation: 'The cat that from the mouse fled$_{[sg]}$ …'). The authors proposed that the syntactic reprocessing account for the P600 effect should be extended to a more general process of reanalysis, more specifically, a monitoring process (e.g., Kolk & Chwilla, 2007; Kolk et al., 2003; Van Herten et al., 2006; Van Herten et al., 2005; Vissers et al., 2006, 2007; Vissers et al., 2008). According to this monitoring hypothesis, as in language production there is monitoring in language perception. A conflict arises when the reader is highly expecting a certain linguistic event (e.g., based on world knowledge, the interpretation that the mice flee from the cat) but encounters another unexpected linguistic event (e.g., based on the sentence parse, the interpretation that the cat flees from the mice). This conflict brings the language system into a state of indecision and triggers reanalysis. The function of the reanalysis is to check the input for possible processing errors which gives rise to the P600 effect. The entire process entailing a response conflict (that exceeds a certain threshold; for details see below), reanalysis and resolution, is referred to as monitoring.

This monitoring process is similar to the one by which we discover perceptual errors like, '*Into a posing camp*' (produced utterance: '*Into opposing camps*'), in which the context will render it likely to the listener that (s)he misunderstood the speaker and that (s)he will ask the speaker to repeat again what was said. In case of a reading error, it is likely that the reader will go back to check whether the reading was correct. A conflict between what is expected in the current context and what is perceived triggers these checking behaviors. The idea that *conflict* is an essential part of the monitoring process is not new; Yeung et al. (2004) proposed this for the Error Related Negativity (ERN) component. The ERN is a negative deflection in the EEG that is seen when participants make an error in a wide variety of psychological tasks (e.g., Holroyd & Coles, 2002). According to Yeung et al. (2004) the ERN signals that a response conflict has occurred between two incompatible interpretations and this brings the system to correct the error.

The monitoring hypothesis can account for the fact that syntactic violations, garden-path sentences, semantic verb-argument violations, and semantic reversal anomalies trigger a P600 effect. In all instances a certain linguistic event (e.g., a certain morpheme) is expected but an unexpected one is encountered, causing a conflict and a monitoring response: “Did I read that correctly?”. Moreover, a monitoring process might explain the fact that a P600 effect was found for sentences with a more complex structure (Kaan et al., 2000). These sentences are more difficult and the chance of conflicting representations is higher. Therefore, monitoring for errors may underlie the P600 effect in these sentences (Van Herten et al., 2006).

Since the first proposal of the monitoring theory for language perception (Kolk et al., 2003), different studies have been conducted to test this theory. In a study by Van Herten et al. (2006) it was found that implausible sentences that contained plausible sentence parts (e.g., ‘*Jan zag dat de eekhoorn het brood bakte ...*’, literal translation: ‘John saw that the squirrel the bread baked ...’) elicited a P600 and not an N400 effect at the verb (*baked*). In these sentences a conflict exists between the plausible sentence part (e.g., of baking bread) and the implausibility of the sentence as a whole. To check if the subject NP (the squirrel) was not misread, reanalysing the input for possible processing errors would be meaningful. Furthermore, Vissers et al. (2006) showed that pseudohomophones in high-cloze sentences elicited a P600 (e.g., ‘*In die bibliotheek lenen de leerlingen boekun ...*’, translation: ‘In that library the pupils borrow bouks ...’) while pseudohomophones in low-cloze sentences did not (e.g., ‘*De kussens zijn volgestopt met boekun ...*’, translation: ‘The pillows are stuffed with bouks ...’). In this study a conflict was present at the word level in the high-cloze sentences, between the highly expected word ‘books’ and the observed pseudohomophone ‘bouks’. Again, reprocessing the input for possible processing errors would be meaningful to be sure the word was not misread. A recent study by Vissers and colleagues (2008) studied the effect of picture-sentence mismatches. In this study participants were shown pictures depicting locative relations (e.g., of a circle in front of a square) followed by a sentence that correctly or incorrectly described the picture. It was hypothesized that, in case of a mismatch between picture and sentence, there would be a conflict at the conceptual level between the representation based on the picture and the representation based on the sentence. As predicted, this conflict gave rise to a P600 effect for the mismatching trials.

The above mentioned studies showed that, when there is a conflict between expectancies, error monitoring in language perception can occur at a number of linguistic levels; the sentence, word and conceptual level (see, Vissers et al., 2008). In the present study we zoom in on the size of the conflict, and test the prediction that only a strong conflict between expectancies will trigger reanalysis and a P600 effect, since it would not be efficient for a monitoring process to be elicited by every conflict (e.g., Vissers et al., 2006). We hypothesized that, if this prediction is correct, a P600 should be triggered by strong semantic violations as well. In daily conversation we often encounter mildly unexpected units corresponding to new, important information. This information should be integrated, otherwise no learning will take place. However, sometimes we encounter linguistic information that is highly unexpected and impossible to integrate in the current context. To avoid the risk of integrating wrong information, it would be useful to mistrust what was heard or read, and reanalyze the input for possible errors. We hypothesized that the degree of the unexpected event, and therefore also of the resulting conflict, could be varied by manipulating plausibility. This led to the prediction that only when the implausibility of the sentence, and therefore the conflict between the expected and unexpected linguistic event, is strong enough, reprocessing will take place and a P600 effect should be elicited. In cases where this conflict is not strong enough, like for mildly implausible sentences, an attempt at integration is made and an N400 effect should occur in the absence of a P600.

In the present study, we tested this prediction of the monitoring theory by presenting participants with sentences in which a category exemplar was highly expected given the previous context. Three experimental conditions were compared: plausible, mildly implausible and deeply implausible sentences. The plausible sentences (e.g., '*The eye consisting of among other things a pupil, iris and retina* ...') were used as the control sentences. We hypothesized that the mildly implausible sentences (e.g., '*The eye* *consisting of among other things a pupil, iris and eyebrow ...*’) would trigger a mild conflict between the exemplar from the expected category and the unexpected critical noun. In this case, integration difficulties arise due to the unexpectedness but they are resolved successfully, thereby eliciting an N400 effect. For the deeply implausible sentences (e.g., ‘*The eye consisting of among other things a pupil, iris and sticker* ...’) however, we hypothesized that a strong conflict between the exemplar from the expected category and the unexpected critical noun would occur, causing integration failure and triggering reanalysis, thereby eliciting a P600 effect.

Methods

Participants

Thirty students (26 women; mean age = 21.0 years; age range = 18 to 28 years) participated. All participants were native speakers of Dutch, had no language disability, had no neurological or psychological impairment, had normal or corrected-to-normal vision, and were right-handed. Handedness was assessed with an abridged Dutch version of The Edinburgh Inventory (Oldfield, 1971). Eight participants reported the presence of left-handedness in their immediate family. Participants were paid, or received course credit for their participation.

Materials

176 sentences were constructed in which a word from a certain category was highly expected given the previous context. The expectancy was created by giving two examples of a certain category (e.g., ‘*The eye consisting of among other things a pupil, iris and …*’), which made it highly likely a word from this category would follow and not a word from a different category. In the sentences the verb always came after the critical noun.

The sentences were used in a pilot study with 9 participants (6 women; mean age = 22.3 years; age range = 19 to 25 years), in which participants were asked to give a set of possible one word completions, completions that were related but did not fit the sentence, and completions that did not fit at all. To be sure participants were not influenced by the part of the sentence after the critical word, the sentence was only shown up to the critical position. The words that were obtained in this pilot study were then used in a plausibility judgment task with 20 participants (16 women; mean age = 19.9 years; age range: 18 to 27 years); 10 participants got one half of all the sentences and 10 participants got the other half. In the plausibility test participants had to rate how plausible the words were in the sentences, by giving a number ranging from 1 (very implausible) to 5 (very plausible). Participants rated various words for each sentence, and therefore saw all three different completions for each sentence that were constructed hereafter.

From the plausibility judgment task 99 experimental sentences were constructed with each three versions differing in plausibility: (1) plausible; (2) mildly implausible; (3) deeply implausible (see Table 1, and Appendix 1 of this thesis). To obtain these three conditions, words with a mean plausibility rating of 5, 3 and 1 respectively were used and the three conditions of a sentence only differed in their critical word. The critical words could be maximally three syllables long and for each word the frequency was searched using the CELEX lemma database. The experimental set was constructed in such a way that overall across the three conditions the critical words did not differ in mean length and frequency (both Fs<1). Sentences differed in total length (mean length = 12 words) and the position of the critical word varied across the different sentences.

Table 1. Example of the three sentence types: (1) Plausible, (2) Mildly implausible, and (3) Deeply implausible

Condition	**Sentence**
(1) Plausible	Het oog bestaande uit onder andere een pupil, iris en *netvlies* is erg gevoelig.
	(The eye consisting of among other things a pupil, iris and *retina* is very sensitive.)
(2) Mildly implausible	Het oog bestaande uit onder andere een pupil, iris en *wenkbrauw* is erg gevoelig.
	(The eye consisting of among other things a pupil, iris and *eyebrow* is very sensitive.)
(3) Deeply implausible	Het oog bestaande uit onder andere een pupil, iris en *sticker* is erg gevoelig.
	(The eye consisting of among other things a pupil, iris and *sticker* is very sensitive.)

The translation is given between brackets and the critical word is given in *italics*.

To obtain a more objective measurement of the plausibility of the critical materials, a post-hoc latent semantic analysis (LSA) of the stimuli was carried out[6]. To this aim, the two category exemplars for each sentence (e.g., *pupil* and *iris*, referred to as A and B) and the critical nouns (e.g., *retina, eyebrow,* and *sticker*, referred to as C, D and E) were translated for all stimuli. Six trials were excluded because no translation could be found for a portion of the nouns. Pairwise comparisons were carried out, using the 'General reading up to 1st year college' space. For the plausible sentences, pairwise comparisons were conducted between AB, AC, and BC. Likewise, for the mildly and deeply implausible sentences, pairwise comparisons were conducted between AB, AD, BD, and AB, AE, BE, respectively. An estimate of the semantic similarity value (SSV) between the three words was obtained by computing the mean of the pairwise comparisons per sentence type (e.g., AB+AC+BC/3, for the plausible sentences) (see Chwilla & Kolk, 2005 for a similar approach). The mean SSV for the 93 trials was 0.36 for the plausible, 0.28 for the mildly implausible, and 0.16 for the deeply implausible sentences. An ANOVA indicated that these differences in mean SSV were reliable [$F(2,278)=40.001$, $p<.001$]. Follow-up LSD pairwise comparisons between the three plausibility conditions, revealed that the plausible sentences differed significantly from the mildly implausible and from the deeply implausible sentences (both $ps<.001$). Most important for the present purposes, these analyses revealed a significant difference in semantic similarity value between the mildly and deeply implausible sentences ($p<.001$).

Ninety-nine filler sentences were created in such a way that overall there was an equal number of sentences of the same length and an equal number of correct and incorrect sentences. Sixty-six of the filler sentences did not contain any violation. The remaining 33 filler sentences were low-cloze sentences adapted from Vissers et al. (2006).

[6] LSA (see: http://lsa.colorado.edu/) is a method to obtain the estimated correlations of the co-occurence of word pairs in large text corpora. These estimates have been found to be well correlated with association strength or semantic similarity (Landauer, Foltz, & Laham, 1998). Chwilla and Kolk (2002) showed that LSA is a sensitive method to detect subtle differences in semantic relatedness between words that were 'associatively unrelated' according to other measures, like lexical co-occurence and free association. In addition, Chwilla and Kolk (2005) found that conceptual scripts made of word triplets (e.g., PROMISE – SILENCE – GRAVE), that were not semantically and/or associatively related, did have higher LSA values than script-unrelated word triplets (e.g., VACATION – TRIAL – DISMISSAL). Furthermore, Van Herten et al. (2006) used LSA successfully, to assess the plausibility of sentence parts of their stimuli.

Three experimental lists were created on the basis of these materials, which were presented to an equal number of participants. The three versions of each sentence were counterbalanced across lists, in such a way that each participant saw only one version of a sentence. Therefore, each list contained 33 plausible, 33 mildly implausible and 33 deeply implausible sentences. To each list the 99 fillers were added. Each list consisted of four blocks with pauses in between. Within each block the trials were pseudo-randomized using the following constraints: each block began with two filler trials, a filler or experimental trial never occurred more than three times in a row, each sentence type condition never occurred more than three times in a row, and a violation (yes/no) never occurred more than three times in a row.

Procedure

Participants were tested individually, seated in front of a computer screen in a dimly-lit Faraday cage. The sentences were presented at the centre of the computer screen in serial visual presentation mode. The words were presented in black capitals on a white background in a 10 cm by 2 cm window and viewing distance was approximately 1 m.

Trials began with a fixation cross (duration 510 msec) followed by a 500 msec blank screen. Then the sentence was presented; word duration was 345 msec and the stimulus-onset asynchrony (SOA) was 645 msec. Sentence final words were indicated with a full stop and inter-trial intervals lasted 2000 msec. Participants were instructed to attentively read the sentence. Furthermore, they were instructed to make eye movements, e.g., eyeblinks, in between sentences.

Each block lasted about 10 minutes and participants were given short breaks in between. During these short breaks participants were given a recognition task to ensure they were attentively reading the sentences. The task consisted of a couple of sentences (5 per block) for which participants had to indicate whether they had been presented in the previous block.

EEG-recording

With 27 tin electrodes mounted in an elastic electrode cap the continuous electroencephalogram (EEG) was recorded (Electrocap International). The electrode positions included twelve electrodes placed at locations from the standard International

10/20 system, namely at the frontal (F3, F4, F7 and F8), temporal (T5 and T6), parietal (P3 and P4), and midline (Fz, Cz, Pz and Oz) locations. Furthermore, seven electrodes were placed at anteriorfrontal (F3A, F4A, F7A and F8A), parietal (P3P and P4P) and midline (FzA) locations. Another eight electrodes were placed at locations that have been reported to be sensitive to language manipulations (e.g., Holcomb & Neville, 1990), these included: left and right anteriortemporal sites (LAT and RAT: 50% of the distance between T3/4 and F7/8), left and right temporal sites (LT and RT: 33% of the interaural distance lateral to Cz), left and right temporoparietal sites (LTP and RTP: corresponding to Wernicke's area and its right hemisphere homologue: 30% of the interaural distance lateral to a point 13% of the nasion-inion distance posterior to Cz), and left and right occipital sites (OL and OR: 50% of the distance between T5/6 and O1/2). This electrode montage has been used in earlier studies (e.g., Van Herten et al., 2006; Vissers et al., 2006). Figure 1 shows the position of the electrodes.

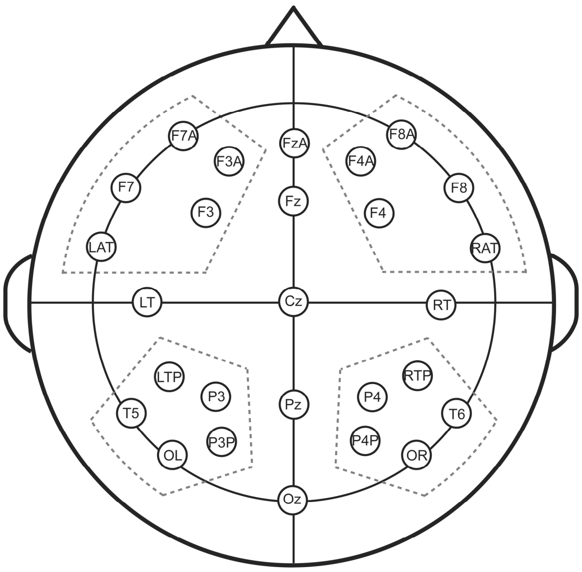

Figure 1. Electrode montage used in the present experiment.

Both the left and right mastoid were recorded and the right mastoid served as reference. The signal was re-referenced to the average of the left and right mastoid before the analysis. Eye blinks and eye movements were recorded by horizontal EOG electrodes next to both eyes and vertical EOG electrodes placed below and above the right eye. The ground was placed on the forehead, in between both eyes. For the EOG electrodes the impedance was smaller than 5 kΩ, and for all the other electrodes impedance was smaller than 3kΩ. The EEG and EOG signals were amplified (time constant = 8 s, bandpass = 0.02-30 Hz) and digitized online with a sampling frequency of 200 Hz.

EEG data analysis

EEG and EOG records were examined for artifacts and excessive EOG amplitude (>100 μV) extending from 100 msec before the onset of the critical noun up to 1000 msec following its onset, and contaminated trials were removed. Averages were aligned to a 100-msec baseline period preceding the critical noun.

The ERPs were analyzed in the following way. Mean amplitudes were calculated in an early window (i.e., 300-500 msec) and a late window (i.e., 500-800 msec), capturing N400 and P600 effects, respectively. These windows were based upon visual analysis and corresponded to the time intervals in which maximal differences between conditions were obtained. Repeated measures analyses of variance (MANOVAs) were conducted with plausibility (plausible, mildly implausible, deeply implausible) as factor. The multivariate approach to repeated measurements was used to avoid problems concerning sphericity (e.g., Vasey & Thayer, 1987). To examine laterality effects ERPs at the midline and lateral sites were analyzed in separate MANOVAs. The midline analysis included the additional factor site (FzA, Fz, Pz, Cz, Oz). For the lateral analysis we used a region of interest (ROI: anterior vs. posterior) by hemisphere (left vs. right) by lateral site (F7A, F3A, F7, F3, LAT vs. LTP, P3, P3P, T5, OL vs. F8A, F4A, F8, F4, RAT vs. RTP, P4, P4P, T6, OR) design to explore the ERP effects' distribution across the scalp. Interactions with the factor site were followed up by paired t-tests at the single-site level.

Plausibility (plausible, mildly implausible, deeply implausible) was a within-subject variable in the initial MANOVAs (next to the (lateral) Site, ROI and Hemisphere within-subject variables described above). Significant main effects and interactions of these MANOVAs were followed up by planned simple effect MANOVAs to make comparisons between all pairs of plausibility conditions.

Results

Performance on the recognition task

Mean error rate for the sentences for which the participants had to indicate whether they had been presented in the previous block or not was 7.67% (block 1: 6.67%, block 2: 6.00%, block 3: 9.33%, block 4: 8.67%). Splitting up the errors rates per condition resulted in 9.1% for the deeply implausible sentences (i.e., on 9.1% of the deeply implausible sentences an error was made), for the mildly implausible sentences this was 10%, and for the plausible sentences 7.5%. These error percentages indicate that the participants attentively read the sentences during the experiment.

Event related potentials

Grand average waveforms for all the sentence types, time-locked to the onset of the critical noun, are presented in Figure 2. An early ERP response characteristic for visual stimuli was elicited for all sentence types; an N1 followed by a P2 component, which at occipital sites was preceded by a P1 component. Visual inspection of the waveforms suggests different patterns of brain activity for the mildly and deeply implausible sentences as compared to the plausible sentences (see Figures 3 and 4, respectively, for a direct comparison). The waveforms of the mildly implausible sentences suggest an N400 effect was present; mean amplitude was more negative-going for the mildly implausible than the plausible nouns in the 300 to 500 msec epoch. The waveforms of the deeply implausible sentences however, suggest a biphasic pattern; an N400 effect as well as a central-posterior P600 effect (mean amplitude was more positive going for the deeply implausible than the plausible nouns in the 500 to 800 window) was present. Visual inspection of Figure 2 suggests that the N400 effect is a bit larger for the deeply implausible than the mildly implausible sentences.

Statistical analyses

The mean percentage of trials that had to be rejected because of artifacts and excessive EOG amplitude was 3.84% for the deeply implausible, 5.86% for the mildly implausible and 3.64% for the plausible condition. Report of the ERP results will be restricted to the main effects and interactions that are relevant for the functional interpretation of the condition effects in the present study.

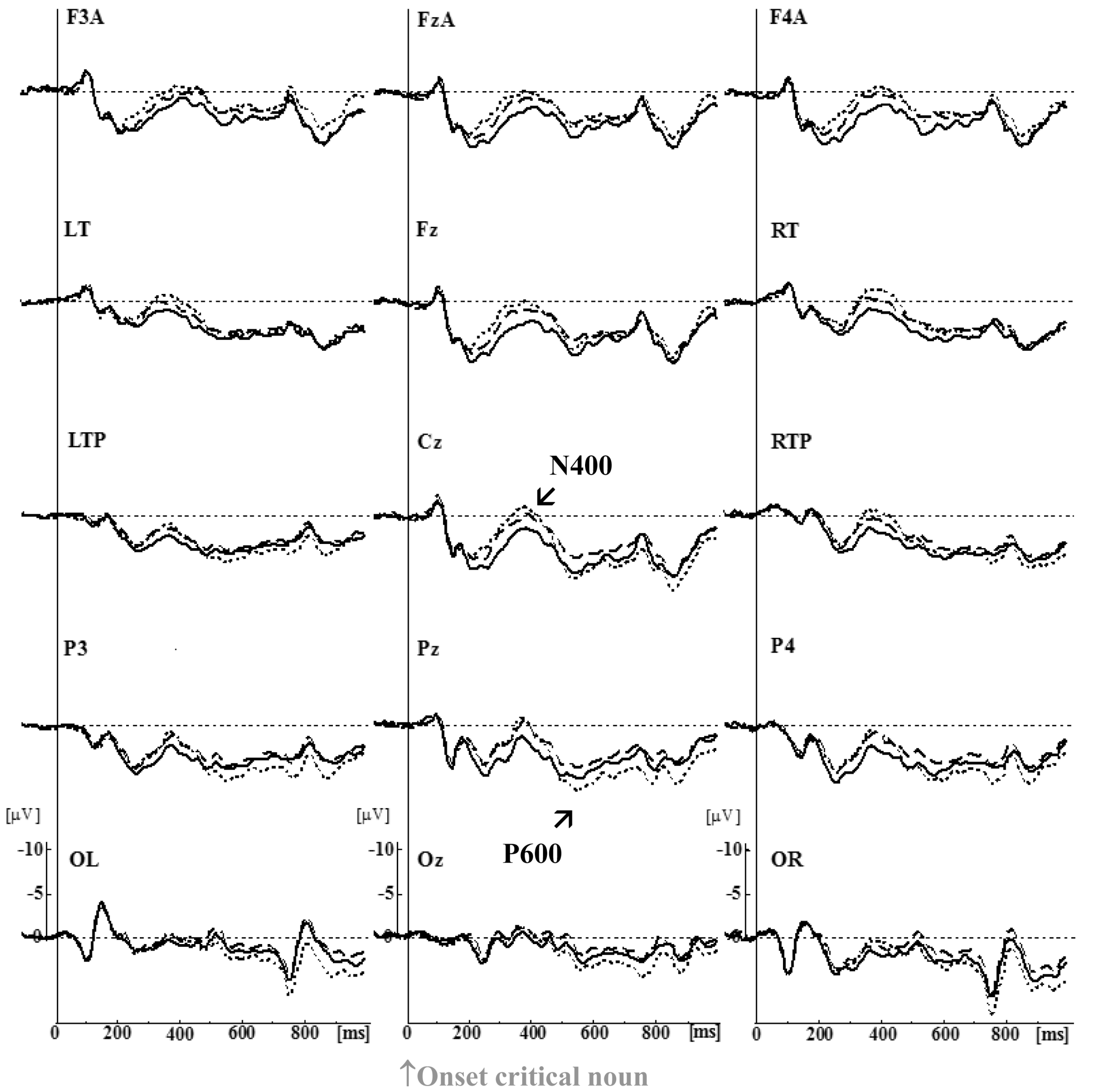

Figure 2. Grand average ERP waveforms to the critical noun for all midline and a subset of lateral sites, for all sentence types: plausible (solid line), mildly implausible (dashed line), and deeply implausible (dotted line).

N400 window (300-500 msec)

The omnibus analysis showed main effects of Plausibility for the midline [$F(2,28)=9.42$, $p<.001$] and lateral sites [$F(2,28)=9.47$, $p<.001$]. Furthermore a Plausibility x Site interaction was present for the midline [$F(8,22)=3.40$, $p<.05$] and lateral sites [$F(8,22)=3.12$, $p<.05$]. The analysis for the lateral sites yielded a Plausibility x Hemisphere [$F(2,28)=3.77$, $p<.02$], Plausibility x ROI [$F(2,28)=5.49$, $p<.05$], Plausibility x Hemisphere x Site [$F(8,22)=2.46$, $p<.05$] and Plausibility x ROI x Site [$F(8,22)=3.15$, $p<.02$] interaction.

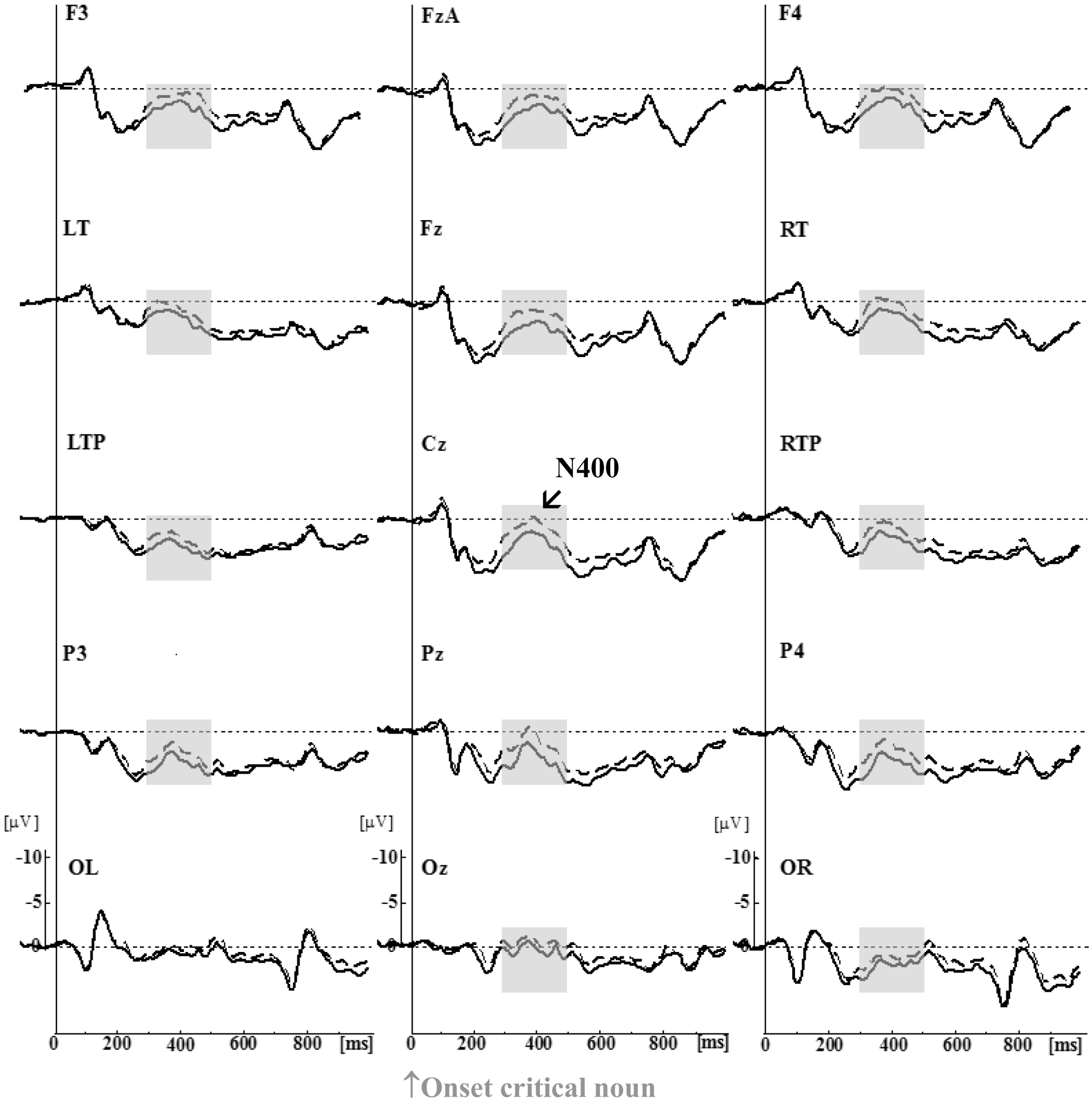

Figure 3. Grand average ERP waveforms to the critical noun for all midline and a subset of lateral sites, for the mildly implausible (dashed line) vs. plausible sentences (solid line).

Mildly implausible vs. plausible sentences

Follow-up analyses for the midline sites, comparing the mildly implausible with the plausible sentences revealed an effect of Plausibility [$F(1,29)=18.85$, $p<.001$] in the absence of an interaction of this factor with Site, indicating that an N400 effect was obtained across the midline. For the lateral sites, an effect of Plausibility [$F(1,29)=17.34$, $p<.001$], a Plausibility x Site [$F(4,26)=3.63$, $p<.05$], and a Plausibility x Hemisphere x Site interaction [$F(4,26)=4.35$, $p<.01$] were present. Single-site analyses indicated that an N400 effect was obtained at anteriorfrontal (F3A, F4A, F7A, F8A), frontal (F3, F4, F7, F8),

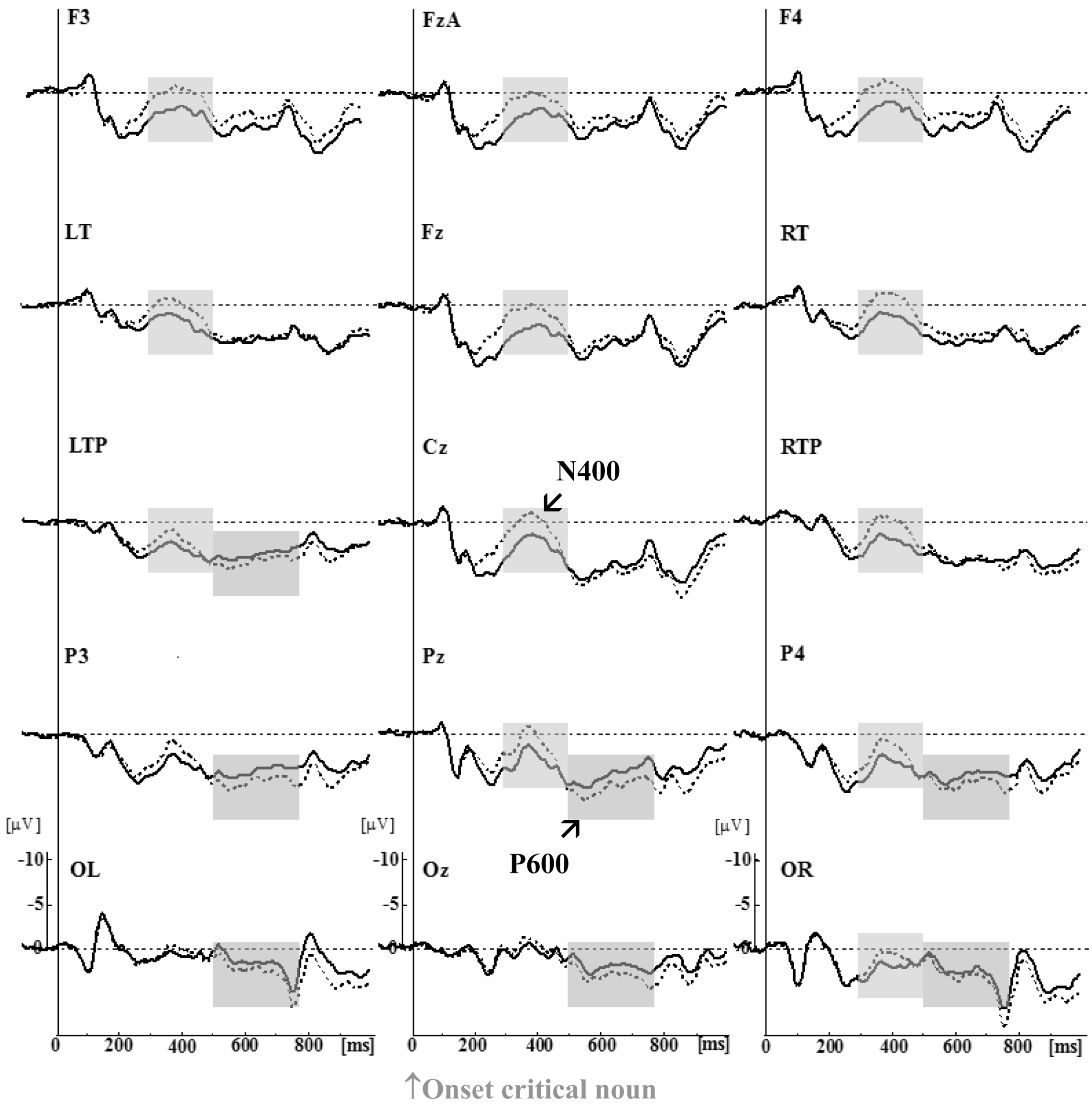

Figure 4. Grand average ERP waveforms to the critical noun for all midline and a subset of lateral sites, for the deeply implausible (dotted line) vs. plausible sentences (solid line).

anteriortemporal (RAT), temporal (LT, RT, T6), temporoparietal (LTP, RTP), parietal (P3, P4, P3P, P4P), and occipital sites (OR) (See Figure 5 for the topographical map).

Deeply implausible vs. plausible sentences

Follow-up analyses for the midline sites, comparing the deeply implausible with the plausible sentences, revealed an effect of Plausibility [F(1,29)=8.56, p<.01], and a Plausibility x Site interaction [F(4,26)=4.44, p<.01]. Single-site analyses indicated that an N400 effect was obtained at the following midline sites: FzA, Fz, Cz, Pz. For the lateral sites, an effect of Plausibility [F(1,29)=13.48, p<.001], a Plausibility x Site [F(4,26)=3.70, p<.05], Plausibility x Hemisphere [F(1,29)=7.07, p<.05], Plausibility x ROI [F(1,29)=9.87, p<.01], and a Plausibility x ROI x Site interaction [F(4,26)=6.64, p<.001] were present. The interactions for the lateral sites reflected that an N400 effect was present at the following bilateral sites: F3A, F4A, F7A, F8A, F3, F4, F7, F8, LAT, RAT, LT, RT, LTP, RTP, as well as at T6. Furthermore, only for the right hemisphere the N400 effect extended to parietal (P4) and occipital (OR) sites (See Figure 5 for the topographical map).

Deeply implausible vs. mildly implausible sentences

Follow-up analyses comparing the deeply with the mildly implausible sentences revealed no effect of Plausibility [midline: F(1,29)=.01, p>.05; lateral: F(1,29)=1.96, p>.05]. However, for the lateral sites there was a Plausibility x ROI [F(1,29)=7.01, p<.05] and Plausibility x Hemisphere x Site interaction [F(4,26)=3.27, p<.05]. Separate analyses for the two levels of ROI (anterior, posterior) revealed a larger N400 amplitude to the deeply implausible sentences for the anterior [F(1,29)=6.71, p<.05], but not for the posterior ROI [F(1,29)=.05, p>.05]. Single-site analyses indicated that an N400 effect was obtained for the following subset of sites: F7A, F7, F8, LAT, RAT, and RT.

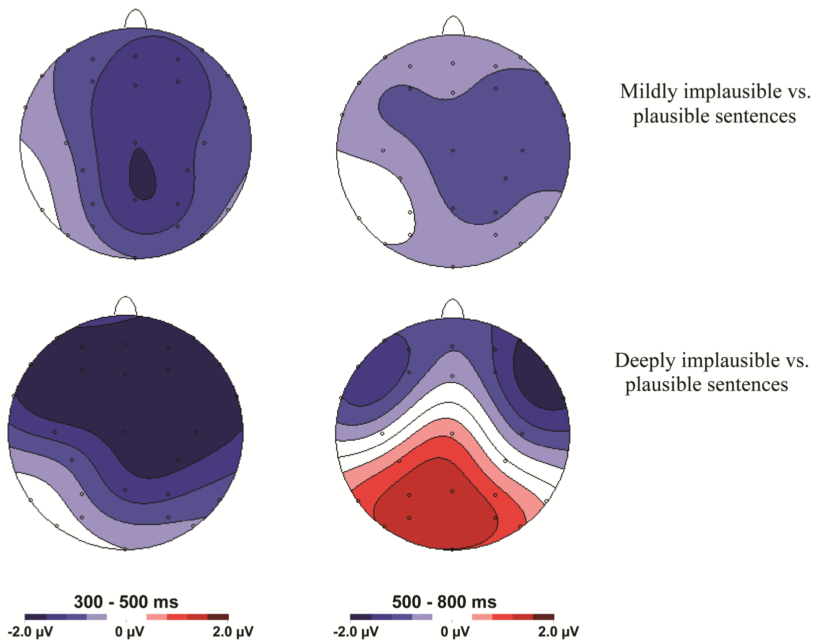

Figure 5. Topographical maps obtained by interpolation from 27 sites for the N400 window (300-500 ms) and the P600 window (500-800 ms). Maps were computed from the difference waves of the mildly implausible vs. plausible (first row) and deeply implausible vs. plausible (second row) sentences.

P600 window (500-800 msec)

The omnibus analysis showed main effects of Plausibility for the midline sites [F(2,28)=6.33, p<.01] and the lateral sites [F(2,28)=3.89, p<.05]. Furthermore, a Plausibility x Site interaction was present for the midline [F(8,22)=5.20, p<.001] and lateral sites [F(8,22)=2.68, p<.05]. In addition, the analysis for the lateral sites yielded a Plausibility x ROI interaction [F(2,28)=26.35, p<.001].

Mildly implausible vs. plausible sentences

Follow-up analysis comparing the mildly implausible with the plausible sentences revealed an effect of Plausibility at the midline [F(1,29)=6.25, p<.05] and lateral sites [F(1,29)=7.60, p<.05]. This indicated that, across the midline and lateral sites, an effect in the opposite direction was obtained; mean amplitude in the P600 window was more negative going for the mildly implausible than the plausible sentences, reflecting a continuation of the N400 effect in the later window (for discussion see below) (See Figure 5 for the topographical map).

Deeply implausible vs. plausible sentences

Follow-up analysis comparing the deeply implausible with the plausible sentences revealed no effect of Plausibility for the midline sites [F(1,29)=.97, p>.05]. However, there was a Plausibility x Site interaction [F(4,26)=4.28, p<.01], which indicated that a P600 effect was obtained at Pz and Oz. For the lateral sites, no effect of Plausibility [F(1,29)=.43, p>.05] was present as well. However, a Plausibility x Site [F(4,26)=3.84, p<.05] and a Plausibility x ROI interaction [F(1,29)=47.67, p<.001] were present. Separate analyses for the two levels of ROI revealed an effect for the anterior [F(1,29)=9.73, p<.01] and posterior ROI [F(1,29)=7.92, p<.01]. For the posterior ROI, a P600 effect was obtained at the following sites: T5, LTP, P3, P4, P3P, P4P, OL, and OR. In contrast, for the anterior ROI, an effect in the opposite direction was found at a subset of sites: F3A, F4A, F7A, F8A, F3, F4, F7, F8, LAT, and RAT, reflecting an extension of the N400 effect into the P600 window (See Figure 5 for the topographical map).

Deeply implausible vs. mildly implausible sentences

Follow-up analysis comparing the deeply with the mildly implausible sentences revealed an effect of Plausibility [$F(1,29)=9.81$, $p<.01$], and a Plausibility x Site interaction [$F(4,26)=9.29$, $p<.001$] at the midline sites. Single-site analyses indicated a P600 effect was obtained for the following subset of sites: Cz, Pz, and Oz. For the lateral sites, a Plausibility x Site interaction [$F(4,26)=5.81$, $p<.01$], and a Plausibility x ROI interaction [$F(1,29)=32.40$, $p<.001$] were found. Separate analyses for the two levels of ROI revealed an effect of Plausibility for the posterior [$F(1,29)=16.38$, $p<.001$], but not for the anterior ROI [$F(1,29)=2.98$, $p>.05$]. Single-site analyses revealed a P600 effect at the following lateral sites: T5, T6, LTP, P3, P4, P3P, P4P, OL, and OR. An effect in the opposite direction was found for two anterior electrodes: LAT and F8.

Discussion

The main results of the present study were as follows. First, as predicted, the mildly implausible sentences elicited an N400 effect at the critical noun when compared to the plausible sentences. Second, an N400 effect was also observed for the deeply implausible sentences, when the critical noun was compared to that of the plausible sentences. This N400 effect for the deeply and mildly implausible sentences was broadly distributed across the scalp. Third, and most importantly, in accordance with the prediction of the monitoring theory, only the deeply implausible sentences elicited a P600 effect when compared to the plausible sentences. The latent semantic analysis confirmed that the deeply implausible sentences were indeed less semantically plausible than the mildly implausible sentences, as reflected by significant differences in semantic similarity values. The P600 effect to deeply implausible sentences resembled the P600 effect found to semantic anomalies and syntactic violations and ambiguity (e.g., Friederici et al., 1993; Van Herten et al., 2005), in terms of the timing and the central-posterior scalp distribution of the effect (see Figure 5).

As was mentioned in the introduction it is generally believed that the N400 reflects semantic processing, more specifically integration difficulties (e.g., Chwilla et al., 1998; Holcomb, 1993; Van Berkum et al., 1999). In the present study we found an N400 effect for both the mildly and deeply implausible sentences, indicating that in both conditions integration difficulties arose. However, for the mildly implausible sentences, the absence of a P600 effect reflected that these integration difficulties were resolved. In contrast, for the deeply implausible sentences integration failed, which we propose triggered a process of reanalysis as reflected by the presence of a P600 effect.[7] Recent studies conducted on thematic role animacy violations (e.g., Kuperberg, Sitnikova, et al., 2003), semantic verb-argument violations (e.g., Kim & Osterhout, 2005) and semantic reversal anomalies (e.g., Kolk et al., 2003; Van Herten et al., 2006; Van Herten et al., 2005) did not report a biphasic N400-P600 pattern, but only a P600 effect to the semantic anomalies. As argued by Van Herten et al. (2006), in most studies where a 'semantic P600' has been observed, an N400 reflecting integration difficulties did not occur as well because a plausibility heuristic, taking into account content words alone, led to a plausible interpretation for both the plausible and the implausible sentences. In our implausible sentences however (e.g., '*The eye consisting of among other things a pupil, iris and eyebrow/sticker ...*'), both the content words on their own and the regular parse would deliver an implausible interpretation for both the mildly and the deeply implausible sentences. So both should indeed show an N400 effect.

On the other hand, the P600 was thought to reflect syntactic processes, but this view has been challenged, since P600 effects have been found to semantic verb-argument violations (e.g., Kim & Osterhout, 2005; Kuperberg et al., 2006; Kuperberg, Sitnikova, et al., 2003) and semantic reversal anomalies (e.g., Kolk et al., 2003; Van Herten et al., 2005), as well as pseudohomophones in high-cloze sentences (Vissers et al., 2006), and picture-sentence mismatches (Vissers et al., 2008).

One view is that the P600 reflects syntactic (re)processing consequent upon grammaticality violations, sentence ambiguity, or a high degree of complexity (e.g., Friederici et al., 1993; Hagoort et al., 1993; Kaan et al., 2000; Münte et al., 1998; Osterhout & Holcomb, 1992). However, the sentences in our deeply implausible

[7] The N400 effect to the mildly implausible sentences was significant at anterior and posterior sites for both the left hemisphere and the right hemisphere. For the deeply implausible sentences, the N400 effect was significant at anterior sites and right posterior sites, while the effect for the posterior part of the left hemisphere was limited to one site (LTP). This distribution difference could be taken to indicate that (partly) different cognitive processes contributed to the N400 effect in the mildly and deeply implausible condition. Based on the present data we cannot rule out this possibility with certainty. However, we think that the same cognitive process (i.e., of semantic integration) elicited the N400 effect in the two conditions. What we propose did differ between the two conditions was the resolution of the integration difficulties, which only in the case of the deeply implausible sentences, where the initial attempt at integration failed, triggered reanalysis.

condition did not contain any syntactic violation, were unambiguous and had the same structure as the other two experimental conditions, meaning these factors cannot have triggered the P600 effect in the deeply implausible sentences. Kuperberg et al. (2003) and Kim and Osterhout (2005) proposed that semantic verb-argument violations elicited P600 effects, because they triggered processes of thematic role reassignment. Thematic role reassignment however, cannot account for the P600 effect found in the present study because the verb was presented after the critical noun and no roles therefore could have been assigned yet. A second factor proposed by Kuperberg (2007), in her review on P600 effects elicited by semantic anomalies, is animacy. Many verbs used in the studies with semantic verb-argument violations had an inherent thematic structure (agent/experiencer-theme), which was violated by an inanimate agent NP. In the present study about 19% of the sentences of the deeply implausible sentences contained an animacy violation with respect to the mentioned category (e.g., '*Animals at that farm like chickens, pigs and pits have* ...'). To determine whether animacy violations could have played a critical role in eliciting a P600 effect to deeply implausible sentences, supplementary analyses were conducted. In these analyses, we excluded those items in which an animacy violation occurred. To keep the number of sentences constant across conditions, all three versions of a trial were removed (i.e., plausible, mildly implausible, deeply implausible). With these supplementary analyses, essentially the same results as with the original analyses were obtained. In particular, when comparing the mildly and deeply implausible sentences with the plausible sentences, a significant central-posterior distributed P600 effect was present for the deeply implausible sentences but not for the mildly implausible sentences. Based on these results we can reject the hypothesis that the P600 effect to the deeply implausible sentences was due to animacy violations.

How then can we account for the P600 effect elicited in the present study? The monitoring theory provides a possible answer. According to the monitoring hypothesis, the P600 reflects a more general process of reanalysis to check for possible processing errors (e.g., Kolk & Chwilla, 2007; Kolk et al., 2003; Van Herten et al., 2006; Van Herten et al., 2005; Vissers et al., 2006, 2007; Vissers et al., 2008). The reanalysis is triggered by a strong conflict between an expected and unexpected linguistic event; in our deeply implausible sentences these events are the exemplar from the expected category and the noun that is actually presented. The expectancy in the present study was created by giving two examples of a certain category, making it very likely a word from this category would follow and not a word from another category. When the conflict is strong enough, as in our deeply implausible sentences, reanalysis is triggered, eliciting a P600 effect. All the above mentioned studies have in common that a certain linguistic event is highly expected but another unexpected linguistic event is encountered. A conflict arises between the two expectancies and reanalysis is triggered to check the input; "Did I read that correctly?". This monitoring process is proposed to be reflected by the P600 effect. It is important to point out that according to the monitoring theory *all* aspects of the input are reanalyzed –that is, the semantic, syntactic, orthographic, as well as phonological aspects of the stimulus all are taken into account (Vissers, 2008). Furthermore, it is assumed that depending on the type of error, the reanalysis process can focus on a certain aspect of the stimulus (e.g., phonological/orthographic aspects for misspellings (Vissers et al., 2006), and semantic aspects for the violations in the present study). The hypothesized result of the reanalysis process consists of the realization that the perceived error was indeed present, and did not stem from a processing error as such.

A question that comes to mind however, is why low-cloze sentences like '*He spread the warm bread with socks*' (Kutas & Hillyard, 1980c) do not elicit a P600? In these sentences a certain linguistic event is highly expected as well and another unexpected linguistic event is encountered, which therefore should create a strong conflict, give rise to reanalysis and thus elicit a P600 effect. However, for these semantic anomalies, an N400 effect and not a P600 effect has generally been reported in the literature. With the present study, we are not able to answer this question conclusively, since another sentence paradigm was used, in which not cloze probability, but plausibility was varied. However, we do have some suggestions as to why we did find a P600 effect, while other studies with strong semantic violations did not.

One factor that could influence why previous studies with very implausible sentences did not report a P600 effect, while the present study did, is the type of sentences that we used, which presumably constrained the range of possible interpretations by creating a high expectancy for an exemplar from a particular category. In a recent study, Federmeier, Wlotko, De Ochoa-Dewald and Kutas (2007) examined the effects of expectancy (cloze probability) and sentence constraint on the ERP response to words. For strongly constraining sentences (e.g., '*Sam could not believe her story was…*'), the best completion (the expected word, e.g., *true*) had a mean cloze value of 83.5%, and the second best completion had a mean cloze value of 4.9%. For the weakly constraining sentences (e.g., '*I was impressed by how much he…*') however, mean cloze value was 26.9% for the expected word (e.g., *knew*), while the second best completion had a mean cloze value of 9.3%. The unexpected, low cloze words (e.g., *published*, in the previous two sentence examples), were matched for cloze probability. By varying constraint, a strong competitor was present when the unexpected word was perceived in the strongly constraining sentences, while the same unexpected word perceived in the weakly constraining sentences, had a couple of relatively weak competitors. In the experiment, a positivity between 500 and 900 msec was found, following the N400 effect, to unexpected words in strongly constraining sentences. This positivity was not observed when the same unexpected words were used in weakly constraining sentences, or when expected words ended the sentences (Federmeier et al., 2007). Relating this to the present study, in the strongly constraining sentences, a certain word was highly expected based on cloze probability, thereby creating a strong conflict when the unexpected word was perceived and eliciting a positivity. In contrast, the weakly constraining sentences did not create a high expectation for a certain word, and therefore no strong conflict was triggered upon perceiving the unexpected word. In the present study the same sentence context was used for all conditions, meaning that a strongly constraining context was present for both mildly and deeply implausible sentences. However, due to our plausibility manipulation and as confirmed by the LSA, the context fit for the critical words in the deeply implausible sentences was smaller than that in the mildly implausible sentences, despite of the fact that both critical words had a cloze value of zero. Therefore, in the deeply implausible sentences, a stronger conflict was present between the exemplar from the expected category and the perceived noun, hence a P600 effect was elicited. A difference with the present study that must be noted, however, is that the positivity Federmeier et al. (2007) found had a frontal distribution, while in the present study a central-posterior distribution was observed. This difference in topography might be related to the fact that in the study by

Federmeier et al. (2007), all the unexpected endings were plausible, while in the present study this was not the case.

Another factor that could explain the discrepancy in results between studies (the occurrence of either an N400 or P600 to semantic anomalies), is component overlap. In the present study, it was found that, across the scalp, the N400 effect prolongated into the P600-window when comparing the mildly implausible with the plausible sentences. This was also the case, for the anterior sites, when comparing the deeply implausible with the plausible sentences. When inspecting Figure 3 it can be seen that the negative shift of the mildly implausible sentences in the N400 window continues into the P600 window; after 500 msec the waveform does not align with that of the plausible sentences. Therefore, the N400 effect could be counteracting the positive shift of the P600 component. When looking at Figure 2 this seems to be a valid hypothesis. In this figure the mildly and deeply implausible sentences can be compared. As the results have shown, both elicit an almost comparable N400, which could have cancelled out the influence of this component on the P600 window when comparing the sentences to each other and shows the P600 effect for the deeply implausible sentences more clearly than when these are compared to the plausible sentences. An example of a study that reported possible component overlap is the study by Schwarz, Kutas, Butters, Paulsen and Salmon (1996). They found, subsequent to an N400 effect elicited by semantically unrelated trials in a category priming task, a positivity over the left hemisphere between 600 and 800 msec for elderly participants, but not for young participants. They hypothesized that, since the amplitude of the N400 effect was larger for young as compared to elderly participants, the subsequent positivity for young participants was masked. In other words: because the N400 amplitude was smaller in elderly participants, the obscuring effect of this negativity was minimized and the late positivity could be seen.

Like the study by Schwarz et al. (1996) mentioned above, Heinze, Muente and Kutas (1998) and Núñez-Peña and Honrubia-Serrano (2005) found that, in a category verification task, a positivity followed the N400 effect to non-members of a semantic category. Furthermore, there have been various other studies that found that the N400, elicited by semantically incongruous sentence completions, was followed by a larger positivity. For example, Woodward et al. (1993) and Ford et al. (1996), both presented a subset of congruous and incongruous sentences from among those used in various studies by Kutas and Hillyard (1980a, 1980b, 1980c), and it was found that the N400 to incongruous sentence completions was accompanied by a larger late positivity. Gunter et al. (1992) also found a positivity following the N400 effect to incongruous sentence endings, and Swick et al. (1998) even hinted at a 'post-sentence error monitoring process' for the positivity they found between 600 and 900 msec, following the N400 elicited by incongruous sentence endings.

In light of the studies that show a larger positivity following the N400 effect to semantically incongruous sentences, Van Petten and Luka (2006) speak of a 'post-N400 positivity', and they note that little research has been done in trying to determine the relevant factor(s) influencing when a monophasic N400 effect ór a biphasic pattern will occur. In the present study, we were able to differentiate between these two patterns within participants by manipulating plausibility. With this we do not want to imply that plausibility is the only factor of influence, for example, yet unknown properties of the stimulus materials may play a role, as well as individual processing strategies. However, further research is needed to find out why a larger positivity sometimes follows the N400 to semantically incongruous stimuli and sometimes does not.[8]

When looking at the stimuli of the present experiment the question might arise whether the positivity that we have found is not a P600 but a P3b component due to an oddball effect. In the classical oddball paradigm on each trial 1 of 2 events can occur with a certain probability (e.g., long auditory tones 80%, and short auditory tones 20%), and the rare events elicit a larger P3b (Donchin, 1981). In the present experiment the conditions had an equal probability overall, but since we used summations within our sentences (e.g., '*… pupil, iris and sticker …*'), some might argue that the positivity we found in our deeply implausible sentences is a P3b component due to an oddball effect, elicited by the rare event of the third noun in the summation not matching the category

[8] In addition to the differences in studies regarding the presence of either a monophasic N400 effect or a biphasic pattern to semantically incongruous endings, inconsistencies have also been shown in the literature on metaphor comprehension. In particular, some studies did not find a positivity following the N400 effect to metaphors (e.g., Arzouan, Goldstein, & Faust, 2007; Pynte, Besson, Robichon, & Poli, 1996), while others did find a biphasic pattern (Coulson & Van Petten, 2002). Coulson and Van Petten (2002) interpreted the late posterior positivity as reflecting the recovery and integration of additional information from semantic memory, which might have been triggered by the earlier semantic mismatch (N400). The monitoring theory could account for the positivities found to metaphors as well; a strong conflict between the representation based on the literal meaning and the metaphorical meaning of the sentence triggers reanalysis.

of the other two. To date, it is debated whether the P600 elicited by syntactic violations, and the P3b elicited by rare non-linguistic events, belong to the same family of P300 components. Some (e.g., Coulson, King, & Kutas, 1998; Gunter, Stowe, & Mulder, 1997) argue that the P600 and P3b resemble each other, and (at least in part) reflect a domain-general process elicited by rare events. Others (e.g., Osterhout & Hagoort, 1999; Osterhout, McKinnon, Bersick, & Corey, 1996) have found that these components are at least to a certain degree distinct, and therefore they reason that a part of the neural and cognitive processes should differ. The monitoring theory proposes that the P600 and P3b could be related (e.g., Van Herten et al., 2005; Vissers et al., 2008), in the sense that both components can be triggered by an unexpected event, have shown similar scalp distributions, and fall within the same time range. However, what sets them apart, speaking of the cognitive processes, might be understood by the type and complexity of the information that has to be reanalyzed (linguistic vs. non-linguistic), which could explain latency differences (see Vissers et al., 2008).

As described in the introduction, Levelt's (1983) theory on language production assumed that errors are detected by a process of comparison of the intended and the planned or produced utterance. Such a comparison could not underlie the monitoring of perception however, since the intentions underlying the perceived utterance are unknown. We therefore hypothesized that it is a strong conflict between what was expected and what was perceived that triggers the language system to reprocess the input. Because the conflict brings the system into a state of indecision, it functions as a strong bottom-up signal, that does not require a monitoring process to be detected. This is different from the Levelt theory (1983), which entails intention and planning/output to be constantly monitored, in order for discrepancies to be detected. Our view does bear similarity to the conflict monitoring theory in the action domain (e.g., Yeung et al., 2004). This theory assumes that the anterior cingulate cortex (ACC) monitors response conflict when multiple response tendencies are activated, and when detecting such a conflict, prefrontal areas are 'warned' to increase cognitive control. This theory does not imply a comparator to detect an error; response conflict that exceeds a certain threshold automatically triggers the ACC, which then informs the brain areas responsible for cognitive control processes.

Another view that shows similarities to our monitoring theory is the view of Kuperberg (2007). In her review, Kuperberg (2007) proposes a language comprehension system with at least two interacting processing streams: a semantic memory-based stream and a combinatorial processing stream (sensitive to morphosyntactic and lexical-semantic constraints). A conflict between the outcomes of both streams is thought to trigger continued analysis of the combinatorial stream, reflected by the P600 component. Similar as suggested by the monitoring theory of language perception (e.g., Kolk et al., 2003), Kuperberg (2007) proposes that the P600 effect is triggered by a *conflict* between representations. Furthermore, both views assume that the P600 reflects some form of continued (re)analysis of the input. However, we think that a major difference between the two views is the proposed nature and function of the (re)analysis. The processing account Kuperberg (2007) proposes, is focused on semantic and syntactic aspects of verb argument structure to determine whether a sentence is acceptable or not. In contrast, the monitoring theory proposes a more general function of the reanalysis, in which all aspects of the input are reanalyzed to find out whether a processing error occurred.

To conclude, in support of the monitoring theory, we propose that the P600 reflects a more general process of reanalysis. The present study shows that only when the conflict between the expected and unexpected linguistic event is strong enough, reanalysis is triggered. It would not be efficient for a monitoring process to be activated by every conflict; when still possible, we try to integrate the information into the context, because we assume that what we read is meaningful and something that is relatively unexpected can still be informative. A mild conflict, like the mildly implausible sentences in the present experiment, therefore does not trigger reanalysis and hence no P600 effect occurs.

Acknowledgments

Portions of this research were presented at the 11th NVP Winter Conference in Egmond aan Zee, 2007, and at the 15th Annual Meeting of the Cognitive Neuroscience Society in San Francisco, 2008. We would like to thank two anonymous reviewers for their helpful comments on a previous version of this article, and the ERG group of the DCC for technical assistance.

Chapter 4

Monitoring in language perception: Electrophysiological and hemodynamic responses to spelling violations

This chapter has been published as:

Van de Meerendonk, N., Indefrey, P., Chwilla, D.J., & Kolk, H.H.J. (2011). Monitoring in language perception: Electrophysiological and hemodynamic responses to spelling violations. *NeuroImage, 54*(3), 2350-2363.

Abstract

The monitoring theory of language perception proposes that competing representations that are caused by strong expectancy violations can trigger a conflict which elicits reprocessing of the input to check for possible processing errors. This monitoring process is thought to be reflected by the P600 component in the EEG. The present study further investigated this monitoring process by comparing syntactic and spelling violations in an EEG and an fMRI experiment. To assess the effect of conflict strength, misspellings were embedded in sentences that were weakly or strongly predictive of a critical word. In support of the monitoring theory, syntactic and spelling violations elicited similarly distributed P600 effects. Furthermore, the P600 effect was larger to misspellings in the strongly compared to the weakly predictive sentences. The fMRI results showed that both syntactic and spelling violations increased activation in the left inferior frontal gyrus (lIFG), while only the misspellings activated additional areas. Conflict strength did not affect the hemodynamic response to spelling violations. These results extend the idea that the lIFG is involved in implementing cognitive control in the presence of representational conflicts in general to the processing of errors in language perception.

General introduction

"Mistakes are a fact of life. It is the response to error that counts" (Nikki Giovanni). This quote nicely illustrates that we are bound to make mistakes but that we can also use the thereby obtained information to adjust our behaviour. To learn from our mistakes, however, we must be able to detect them. The detection of errors and the adjustments in behaviour require cognitive control. Cognitive control processes manage and guide other cognitive processes according to internal goals. One aspect of cognitive control is monitoring, which deals with the detection and repair of errors. Errors occur when there is a mismatch between what we intend or expect and what we do or observe. When such a mismatch is detected, compensatory adjustments are triggered in the processing pathways that are involved, leading to a repair.

Mistakes, of course, occur in various domains, and here we are interested in the language domain. In this field, the main focus has been on error monitoring in language production. For language production, researchers have been interested in speech errors and their repairs (for a review see Levelt, 1983). However, in language perception error monitoring takes place as well. For example, sometimes we mishear what another person is saying and ask for a clarification: "Did I understand you correctly…?". Another type of perceptual language errors are mistakes that are made while reading a text. Kaufman and Obler (1995) call these 'slips of the eye', and showed that normal adult readers make various kinds of these errors. For instance, sometimes words are inserted, omitted or exchanged, the parsing of a word or sentence can be erroneous (e.g., reading *posts* as a noun instead of as a verb) or the wrong interpretation of a homonym can be selected (e.g., interpreting *rock* in *rock art* to mean a stone while based on the context it meant a form of music). Of course, there are also mistakes that are actually present in the text itself. For example, while proofreading your article you may encounter some spelling errors. Most of the time we will detect the errors because the interpretation will not fit into the wider context. Based upon this context, expectations are generated and when these are not met, a conflict arises between what was expected and what is observed. This results in a state of indecision: "Did I read that correctly?".

A number of electroencephalography (EEG) studies of language comprehension have linked this process of monitoring for such a representational conflict and triggering of compensatory adjustments to the P600 component. The P600 is a central-posterior distributed, positive-going event-related potential (ERP) component that starts around 500 msec and generally extends up to at least 800 msec. An increase in P600 amplitude has been reported to various syntactic violations (e.g., Friederici et al., 1993; Hagoort et al., 1993; Münte et al., 1998), locally ambiguous garden-path sentences (Osterhout & Holcomb, 1992) and relatively complex sentences compared to simpler sentences (Kaan et al., 2000). These elicitations of a so called P600 effect to syntactic difficulties led to the proposal that the P600 reflects some form of syntactic processing (e.g., Friederici, Hahne, & Mecklinger, 1996; Kaan et al., 2000). However, based on an increase in P600 amplitude to orthographic violations as well as to syntactic violations, Münte et al. (1998) proposed that the P600 does not just reflect syntactic processing but a more general reanalysis. A P600 to spelling violations has recently been replicated in our laboratory (see Vissers et al., 2006).

The hypothesis that the P600 effect reflects a more general reanalysis has been strengthened by a number of recent studies (for reviews on these studies see Kolk & Chwilla, 2007; Kuperberg, 2007; Van de Meerendonk, Kolk, Chwilla, & Vissers, 2009), demonstrating P600 effects to different kinds of semantic anomalies (e.g., Ganushchak & Schiller, 2010; Hoeks et al., 2004; Kim & Osterhout, 2005; Kolk et al., 2003; Kuperberg et al., 2006; Kuperberg et al., 2007; Kuperberg, Sitnikova, et al., 2003; Van de Meerendonk et al., 2010; Van Herten et al., 2006; Van Herten et al., 2005). Furthermore, P600 effects were found to picture-sentence mismatches in which the sentences violated the semantics of a previously shown picture (Vissers et al., 2008). The P600 effects to semantic anomalies were unexpected, as it was the general assumption that semantic anomalies affected the N400, a negative ERP component that peaks around 400 msec after critical word onset (e.g., Kutas & Hillyard, 1984).

According to the monitoring theory of language perception (for a review see Van de Meerendonk et al., 2009), common to all these studies is the assumption that there was a strong expectation for a certain linguistic element which was not met. This resulted in the co-activation of competing representations, i.e., the expected and the observed element. It is proposed that such competing representations trigger a conflict which functions as a bottom-up signal to elicit reprocessing of the input to check for possible processing errors, which is reflected by the P600 effect.

The previously-mentioned EEG studies that investigated monitoring processes in language perception manipulated two different factors: the type of material that elicited a conflict and the conflict strength. As said, various semantic anomalies, picture-sentence mismatches and spelling violations have been studied and it was found that representational conflicts of various types elicit a P600 effect. Some of these studies also directly compared the obtained P600 effects to the P600 effects elicited by morphosyntactic violations (e.g., subject-verb agreement violations) and found similar scalp distributions (e.g., Kuperberg et al., 2006; Van Herten et al., 2005). The second factor, conflict strength, has been manipulated in some studies based on the idea that for reasons of efficiency only representational conflicts that are sufficiently strong (i.e., pass a certain 'threshold') should trigger reprocessing of the input. For example, Van de Meerendonk et al. (2010) induced differences in conflict strength by varying plausibility. In the sentence context the critical words could either be plausible, mildly implausible, or deeply implausible. For instance:

(1) Lichaamsdelen zoals een arm, nek en <u>teen/haar/telescoop</u> … (plausible/mildly implausible/deeply implausible)

Parts of the body like an arm, neck and <u>toe/hair/telescope</u> … (literal translation)

Although both the mildly and deeply implausible condition violated the expectation based on the sentence context, only the deeply implausible condition was predicted to create a representational conflict of sufficient size. Therefore, only for this condition reprocessing and a P600 effect should be triggered. By contrast, it was hypothesized that the mildly implausible condition would lead to integration difficulties that could be resolved without reprocessing the input. The results confirmed these predictions. Compared to the plausible condition, the mildly implausible condition elicited an N400 effect (i.e., a more negative N400 amplitude). The deeply implausible condition elicited an N400 effect followed by a P600 effect. Vissers et al. (2006) manipulated conflict strength by varying cloze probability. The cloze probability of a certain word is the percentage of individuals that complete a sentence with that particular word. Vissers et al. (2006) found a P600 effect to misspelled words when the expected critical word in its correct spelling had a high cloze probability. Misspellings of critical words with a low cloze probability did not elicit a P600 effect.

In a recent study by Ganushchak and Schiller (2010) an effect of conflict strength was indicated as well. In this study participants saw a visual network of coloured objects while listening to a path description through this network. The path description could contain semantic (wrong colour name) or syntactic violations (determiner gender agreement error). An important difference between both types of violations was that colour errors could be detected based on both auditory information and visual information in the network, while determiner gender agreement errors could be detected based on auditory information only. Thus, participants could expect to hear a certain colour based on the visual network, but the retrieval of the concept of the word and its gender was needed to form an expectation for a certain determiner. Because the expectations formed for a certain colour were higher than for a certain determiner, the authors proposed that the semantic violations created a stronger conflict than the syntactic violations. In agreement with this proposal, the results showed that the semantic violations were more often detected than the syntactic ones. Furthermore, the condition with the stronger conflict, the semantic violations, elicited larger P600 amplitudes compared to correct trials, while syntactic violations did not.

Representational conflicts have also been investigated in functional magnetic resonance imaging (fMRI) studies. A brain area that is implicated in several of these studies is the posterior part of the left inferior frontal gyrus (Brodmann’s area (BA) 44 and 45, also referred to as Broca’s area, henceforth indicated as lIFG). The lIFG is part of the prefrontal cortex (PFC), a brain area that is thought to be important for cognitive control. As explained previously, monitoring is an aspect of cognitive control that is important when different responses or representations compete to be selected. The PFC, including lIFG, is thought to be involved in this process through resolving the competition between representations by biasing neural activity in the appropriate pathways (e.g., Miller & Cohen, 2001).

A task involving representational conflict that has been studied extensively in relation to cognitive control is the Stroop task (Stroop, 1935). In this task participants have to name the ink colour of a word and ignore the printed word. In the incongruent condition the ink colour to be named differs from the colour word that is printed (e.g., *red* printed in blue ink), thereby creating a conflict. Cognitive control is needed to shift attention away from the stronger task-irrelevant representation (the printed word) and direct attention towards the weaker task-relevant stimulus information (the ink colour). Incongruent Stroop trials have been found to elicit activation in the lIFG (e.g., see Nee et al., 2007; Novick et al., 2005).

In the language domain, a well-known example in which various representations are co-activated are so called garden-path sentences, which are sentences that are locally ambiguous and have a preferred parse, like :

(2) The broker persuaded to sell the stock …

Garden-path sentences have been observed to elicit a P600 effect in the EEG (e.g., Osterhout & Holcomb, 1992, see previous discussion) and in fMRI they show increased activation in the lIFG (e.g., Mason et al., 2003).

Novick et al. (2005) proposed a unifying account for lIFG findings in the cognitive control literature and the psycholinguistic literature (see also Thompson-Schill, Bedny, & Goldberg, 2005). They proposed that the area is involved in general conflict resolution. To prevent misinterpretations, the lIFG is thought to implement cognitive control when there is a conflict between competing representations by biasing the activation patterns associated with the competing representations. The authors therefore suggest that, analogous to conflict resolution in the Stroop task, recovering from garden-path sentences (i.e., selecting the relevant parse) involves the lIFG to exert cognitive control and shift attention towards the relevant parse. To achieve reanalysis, the initially preferred parse needs to be suppressed and then all the evidence needs to be taken into account to recover the correct parse. In a recent study, January, Trueswell and Thompson-Schill (2009) directly compared the activation in the lIFG during representational conflict in the Stroop task and syntactically ambiguous sentences within subjects. They found that both types of conflict increased activation in the lIFG to a similar extent, and concluded that this is based on a shared conflict resolution mechanism.

Recent fMRI studies of language perception have investigated representational conflicts elicited by semantic anomalies in unambiguous sentences that had previously been shown to elicit P600 effects in the EEG. Kuperberg, Sitnikova and Lakshmanan (2008) tested 'animacy semantic-thematic violations' (see also Kuperberg et al., 2006). The following is an example:

(3) Every morning at breakfast the eggs would <u>eat</u> …

In this sentence, the syntactic parse indicates that the noun phrase (NP) *the eggs* is the agent of the sentence and therefore *eat* would be a syntactically correct verb form. However, the semantic characteristics of the NP in combination with the verb *eat* create the expectation that the NP is the theme of the action and should be accompanied by a passive verb form. The fMRI study revealed that both these animacy semantic-thematic violations and morphosyntactic (subject-verb agreement) violations elicited activation in a widespread network, which included part of the lIFG (BA 44). Another fMRI study of language perception (Ye & Zhou, 2009a) also investigated semantic anomalies in unambiguous sentences, in particular 'semantic reversal anomalies'. Semantic reversal anomalies are sentences in which the representation based on world knowledge and the representation based on the syntactic parse compete (e.g., Kolk et al., 2003; Van Herten et al., 2005; Ye & Zhou, 2008). For example:

(4) The thief <u>kept</u> the policeman in the police station (paraphrase of Chinese example)

Ye and Zhou (2009a) showed that a network of dorsal medial superior frontal gyrus, left inferior parietal lobule (lIPL) and lIFG was activated for these semantic reversal anomalies. In addition, they provided further support for a general conflict resolution mechanism, since the same network was found to be active for the incongruent conditions of Stroop and Flanker[9] tasks (see also Ye & Zhou, 2009b).

In the present study we further explored the representational conflicts underlying the detection and reprocessing of errors in language perception. To this end, we conducted an EEG and fMRI experiment on syntactic and spelling violations. Our purpose was twofold. First, conflicts induced by syntactic and spelling violations have been found to elicit positivities in the EEG with very similar scalp distributions. Therefore, our question was whether we would also find co-localization of activity elicited by syntactic and spelling conflicts in the fMRI, possibly in the lIFG, supporting the assumption of a role of this area in general conflict resolution. Secondly, we were interested whether the effect of a conflict strength manipulation on the processing of spelling violations would also modulate the hemodynamic response in the fMRI.

[9] In the Flanker task (Eriksen & Eriksen, 1974) people have to respond to, for example, a central arrow that is surrounded by other arrows. In the incongruent condition the central arrow is surrounded by arrows that point in a different direction (e.g., →→←→→) .

Whether or not the hemodynamic response of a certain region is affected by the strength of a representational conflict could be informative with respect to its role in the processing of a conflict and/or subsequent reanalysis processes.

Vissers et al. (2006) manipulated conflict strength by varying the cloze probability of a misspelled word. In one condition they embedded orthographically incorrect but phonologically correct words (i.e., pseudohomophones) in sentences with a high cloze probability for the critical word (see example 5). In another condition they embedded the misspelled words in sentences with a low cloze probability for the critical word (see example 6).

(5) De kussens zijn opgevuld met verun …
The pillows are stuffed with feathurs … (literal translation)

(6) Haar walkman deed het niet meer vanwege de verun …
Her walkman did not work anymore because of the feathurs … (paraphrase)

Although both conditions contained a spelling violation, Vissers et al. (2006) assumed that only in the high cloze probability condition the critical word in its correct spelling was highly expected. Therefore, in this condition the misspelling should elicit a strongly competing representation resulting in a conflict triggering a P600 effect. In the low cloze probability condition the critical word was not expected, and therefore the misspellings were not assumed to elicit such a strong conflict. The results indeed showed a P600 effect for the high cloze probability misspellings only. Note, however, that the sentences in the low cloze probability condition of Vissers et al. (2006) were created by exchanging critical words between high cloze probability sentences. For instance, example 6 was created from the following high cloze probability sentence:

(7) Haar walkman deed het niet meer vanwege de batterijen …
Her walkman did not work anymore because of the batteries … (paraphrase)

In effect, the sentence contexts in this condition had a low cloze probability for the critical word, but still elicited a high expectation for another word. We hypothesized that this could still have triggered a strong conflict between competing representations of the expected and observed word. An indication in this direction was that Vissers et al. (2006) found correctly spelled critical words in the low cloze probability condition to elicit a biphasic N400-P600 pattern. In a direct comparison between correct and misspelled words, a P600 response to misspellings might thus have been subtracted out.

In the present study we, therefore, used a low cloze probability condition in which the sentence context created no expectation for any particular continuation (see example 8).

(8) Op die plek liggen soms verun …

At that spot there sometimes lie feathurs … (paraphrase)

This cloze probability variation resulted in sentences which were either strongly predictive (high cloze probability) or weakly predictive (low cloze probability) of a certain word, thereby manipulating conflict strength. A stronger representational conflict should be triggered in the case of the high cloze probability misspellings, since the word was expected based on the sentence context as well as incorrectly spelled. For the low cloze probability misspellings the conflict should be weaker, because although the word was misspelled, there was no expectation based on the sentence context.

EEG experiment

Introduction

An EEG experiment was conducted to test whether, as the monitoring theory of language perception hypothesizes, the spelling violations indeed elicited the same central-posterior distributed P600 effect compared to the syntactic violations within subjects. A similar scalp topography would support the view that qualitatively similar brain processes are involved in both conditions. In contrast, a difference in scalp topography would indicate that at least partially different processes are engaged in processing syntactic vs. spelling violations.

In addition, the effectivity of the conflict strength manipulation of the misspellings was tested. Assuming that the representational conflict for the high cloze probability misspellings is stronger, we expected a larger P600 effect for this condition relative to the low cloze probability misspellings.

Materials and methods

Participants

Thirty-two healthy right-handed native speakers of Dutch participated in the EEG experiment. Twenty-eight participants were included in the final analyses (21 women;

mean age = 21.3 years; age range = 18 to 26 years). Four participants were excluded because of excessive eye-movement artefacts or apparatus failure. All participants had normal or corrected-to-normal vision, had no language disability, and had no neurological or psychological impairment. The study was approved by the local ethics committee. Written informed consent was obtained prior to participation. The participants were paid or received course credit for their participation.

Stimulus Materials

Spelling violation materials

The spelling violation materials consisted of 116 high cloze probability and 116 low cloze probability sentences. Critical words in the high cloze probability sentences had a mean cloze probability of 0.91 and were identical to those that were used in the study by Vissers et al. (2006). The novel low cloze probability sentence contexts were tested in a pilot study with 15 participants (10 women; mean age = 24.1 years; age range = 20 to 29 years) and had a mean cloze probability of 0.10. The critical low cloze probability words that were used were all plausible continuations of the sentences and had a cloze probability of 0. The high and low cloze probability sentences were matched for critical word position, length and mean number of clauses.

The critical words were the same in the high and low cloze probability sentences and appeared in mid-sentence position. In different conditions, the critical words were either correctly spelled or misspelled. Spelling violations were created by changing one letter of the word while keeping the phonology the same (see Vissers et al., 2006). This resulted in four sentence conditions: high cloze probability correct, high cloze probability misspelling, low cloze probability correct, and low cloze probability misspelling (see Table 1 for examples, and Appendix 2 of this thesis).

Sixty filler sentences adapted from Vissers and colleagues (2006) were used. These consisted of 30 correct sentences, 10 sentences with spelling violations at the beginning, 10 sentences with spelling violations in the middle, and 10 sentences with spelling violations at the end of the sentences.

Eight experimental lists were created on the basis of these materials, which were presented to an equal number of participants. For each critical word the four sentence conditions were counterbalanced across four lists in such a way that participants saw

Table 1. Example of the four sentence conditions of the spelling materials.

Condition	**Sentence**
high cloze probability correct	De kussens zijn opgevuld met veren waardoor ze zacht aanvoelen. (The pillows are stuffed with feathers which make them feel soft.)
high cloze probability misspelling	De kussens zijn opgevuld met verun waardoor ze zacht aanvoelen. (The pillows are stuffed with feathurs which make them feel soft.)
low cloze probability correct	Op die plek liggen soms veren van fazanten en pauwen. (At that spot there sometimes lie feathers from pheasants and peacocks.)
low cloze probability misspelling	Op die plek liggen soms verun van fazanten en pauwen. (At that spot there sometimes lie feathurs from pheasants and peacocks.)

Note: The critical word is underlined and the translation is given in parentheses.

only one condition of a critical word. Each list contained 29 sentences per condition (high cloze probability correct, high cloze probability misspelling, low cloze probability correct, and low cloze probability misspelling). To each list the sixty filler sentences were added. The lists consisted of two blocks (88 trials each) that contained an equal amount of sentences per condition. The blocks were matched for critical word position and sentence length. The order of these blocks was reversed to create eight experimental lists in total. Within each block the trials were pseudorandomized using the following constraints: each block began with two filler trials, a filler or experimental trial never occurred more than three times in a row, a spelling violation never occurred more than three times in a row, and a certain condition never occurred more than two times in a row. Furthermore, for both the high and low cloze probability sentences, the correct and misspelling trials were equally often preceded by a correct or misspelling trial.

Syntactic violation materials

Fifty-eight experimental sentences were created. Each sentence had two versions: a syntactically correct and a syntactically incorrect version that contained a number agreement violation on the verb (see Table 2 for an example, and Appendix 2 of this thesis). Half of the sentences contained an incorrect singular verb and half an incorrect plural verb. Furthermore, half of the subject NPs had animate and half inanimate referents. The mean length, mean position of the critical word, and mean number of clauses were matched to the spelling experimental materials.

Table 2. Example of the two sentence conditions of the syntactic materials.

Condition	Sentence
syntactically correct	De schone kleren en handdoeken hangen aan de waslijn te drogen.
	(The clean clothes and towels hang out on the clothesline to dry.)
syntactically incorrect	De schone kleren en handdoeken hangt aan de waslijn te drogen.
	(The clean clothes and towels hangs out on the clothesline to dry.)

Note: The critical word is underlined and the translation is given in parentheses.

A post-hoc cloze test with 16 participants (12 women; mean age = 26,4, age range = 23 to 31 years) of the experimental sentences of the syntactic materials indicated a medium cloze probability of 0.50. In this regard the syntactic materials were not matched to the spelling materials for expectancy. Therefore, quantitative direct comparisons between the syntactic and spelling materials will not be conducted.

Thirty filler sentences were created consisting of 15 syntactically correct and 15 syntactically incorrect sentences. The incorrect fillers also contained a number agreement violation on the verb, but compared to the experimental sentences the violations occurred very early in the sentence or later on a second verb. Just as the experimental sentences, the filler sentences were matched to the spelling filler materials for mean length, mean position of the critical word, and mean number of clauses.

On the basis of these materials two experimental lists were created, which were presented to an equal number of participants. The two versions of each sentence were counterbalanced across lists in such a way that participants saw only one version of a sentence. Each list consisted of one block that contained 29 syntactically correct, 29 syntactically incorrect, and 30 filler sentences. The trials were pseudorandomized using the same constraints as for the spelling materials. Syntactically correct and incorrect trials were equally often preceded by a syntactically correct or incorrect trial.

Procedure

The stimuli were presented using the Presentation software (Neurobehavioral Systems, www.neurobs.com). Participants were tested individually seated in front of a computer screen. The words were presented in white capitals on a grey background (maximum visual angle 5.2 degrees) with a word duration of 350 msec and a stimulus-onset asynchrony of 645 msec. Trials began with a fixation cross (duration = 510 msec) followed by a 500 msec blank screen. Inter-trial intervals lasted 2000 msec. Participants were instructed to blink between sentences.

To ensure that the participants attentively read the sentences, 10% of the sentences was followed by a ‘yes’ or ‘no’ question about the previous sentence content. The questions were always preceded by a correct sentence condition and followed by a filler trial. The participants had to respond by pressing a button with the left or right index finger. The questions disappeared from the screen when the participants pressed a button or when they failed to respond within 3 sec. Questions to which the participants failed to respond within 3 sec were counted as an error.

The experiment was divided into 3 runs (2 spelling blocks and 1 syntactic block) that each lasted about 20 minutes. Pauses were given in between the runs. The order of the blocks was counterbalanced across subjects with the provision that the two spelling blocks always followed each other. This ‘blocked design’, in which the spelling and syntactic violations were not mixed, was chosen for comparability to our previous studies and because list composition has been found to influence ERP results (e.g., Chwilla, Kolk, & Mulder, 2000).

Data acquisition and analysis

The EEG was recorded continuously with 27 electrodes mounted in an elastic electrode cap (Electro-Cap International). The montage included 5 midline and 22 lateral sites (see Figure 1). The left mastoid served as a reference. The electro-oculogram (EOG) was recorded by horizontal EOG electrodes with a right to left canthal montage and vertical EOG electrodes placed below and above the right eye. The ground was placed on the forehead, in between both eyes. Electrode impedance was less than 5 kΩ for the EOG electrodes, and less than 3 kΩ for the other electrodes. The signals were amplified (time constant = 8 s, band pass = 0.02-30 Hz) and digitized on-line with a sampling frequency of 200 Hz.

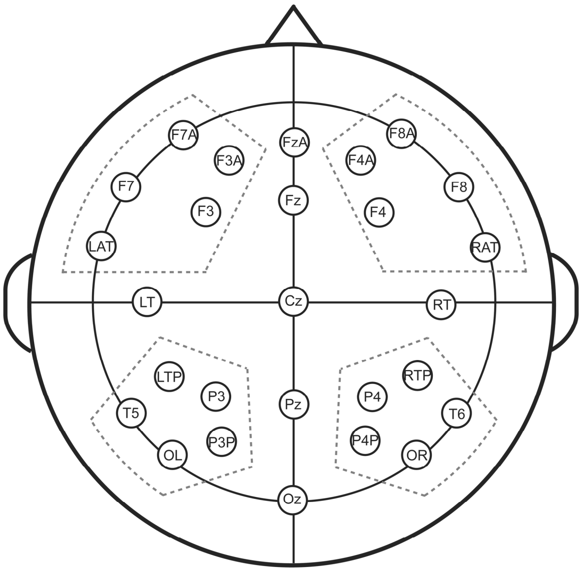

Figure 1. Electrode montage used in the EEG experiment.

Before the analyses, the signal was re-referenced to the average of the left and right mastoids. EEG and EOG records were examined for artefacts and excessive EOG amplitude (>100 µV) from 100 msec before the onset of the critical letter string up to 1000 msec following its onset. Contaminated trials were removed and averages were aligned to a 100-msec baseline period preceding the critical letter string. Based upon visual inspection and previous literature, mean amplitudes were calculated in an early (300-500 msec) and late time window (500-800 msec) to capture the N400 and P600 effects, respectively.

Repeated measures analyses of variance (MANOVAs) were conducted separately for the midline and lateral sites with Syntax (correct and incorrect) as critical factor for the syntactic data and Spelling (correct and misspelling) and Cloze probability (high and low) as critical factors for the spelling data. Next to these critical factors, the midline analyses included the factor Site (FzA, Fz, Cz, Pz and Oz) and the lateral analyses included the factors Region (anterior, posterior), Hemisphere (left, right) and Site. The factors Hemisphere and Region divided the electrodes into four quadrants: left anterior (F7A, F3A, F7, F3 and LAT), left posterior (LTP, P3, P3P, T5 and OL), right anterior (F8A, F4A, F8, F4 and RAT), and right posterior (RTP, P4, P4P, T6 and OR). Interactions with the factor

Site were followed up by paired *t*-tests at the single-site level. To avoid problems concerning sphericity, the multivariate approach to repeated measures was used (e.g., Vasey & Thayer, 1987). The report of the ERP results will be restricted to the relevant effects including the critical factor(s).

Results

Performance on the comprehension task

Mean error rate on the comprehension questions was 10.6% (syntactic part: 11.5%; spelling part: 10.1%). The low error percentages indicate that the participants read the sentences attentively.

Event-related potentials

The mean percentage of trials that had to be rejected because of artefacts and excessive EOG amplitude was 6.65% for the syntactically correct and 6.28% for the syntactically incorrect condition. In the spelling materials this was 8.25% for the high cloze probability correct, 8.62% for the high cloze probability misspelling, 4.92% for the low cloze probability correct, and 5.67% for the low cloze probability misspelling conditions.

Grand-average waveforms for the syntactic data and the spelling data time-locked to the onset of the critical letter string are presented in Figures 2 and 3, respectively. All conditions elicited the for visual stimuli characteristic early ERP response - that is, an N1 followed by a P2 which at occipital sites was preceded by a P1. Visual inspection of the waveforms suggested the presence of a P600 effect for the syntactically incorrect vs. syntactically correct, high cloze probability misspelling vs. high cloze probability correct, and low cloze probability misspelling vs. low cloze probability correct conditions, maximal at central-posterior sites.

In addition, inspection of the waveforms of the spelling data suggested that an N400 effect was present for the high cloze probability misspelling vs. high cloze probability correct, and low cloze probability misspelling vs. low cloze probability correct conditions at left frontal and temporal sites. Furthermore, a broadly distributed standard cloze probability effect (i.e., a more negative N400 amplitude for the low compared to the high cloze probability condition) with a centro-parietal maximum seemed to be present for both the correct words and the misspellings.

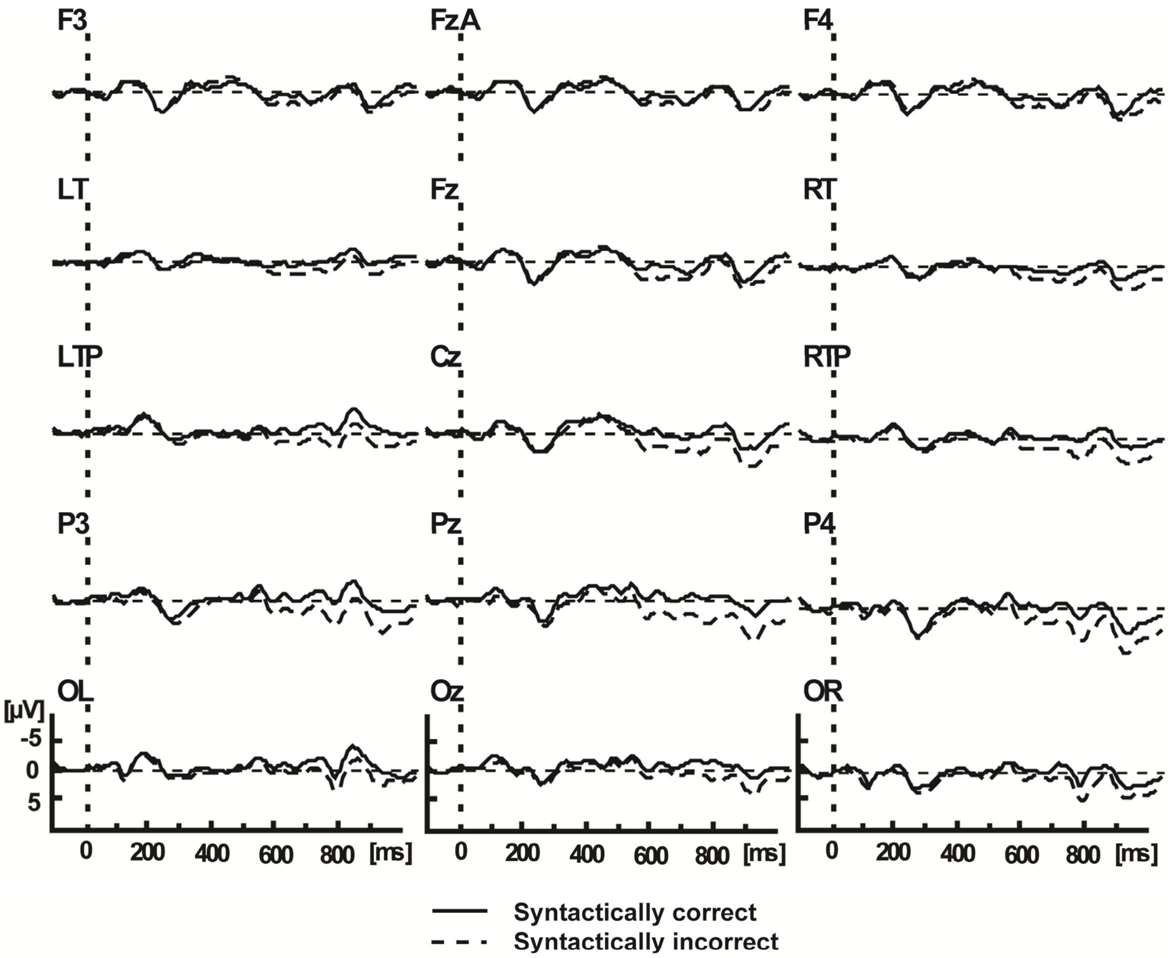

Figure 2. Grand-average ERP waveforms to the critical words for all midline and a subset of lateral sites, for the syntactically incorrect vs. syntactically correct condition.

N400 window (300-500 msec)

No significant results were found within this window for the syntactic data.[10]

For the spelling data, a main effect of Cloze probability for the midline sites [$F(1,27)=60.41$, $p<.001$] and for the lateral sites [$F(1,27)=37.09$, $p<.001$] reflected that overall mean amplitudes were more negative for the low cloze compared to the high cloze probability conditions. For the lateral sites a three-way interaction of Cloze probability x Spelling x Hemisphere was present [$F(1,27)=6.06$, $p<.05$]. Therefore, follow-up analyses were conducted for the two spelling conditions and the two cloze probability levels separately.

[10] Syntactic violations have been found to elicit an Early Left Anterior Negativity (ELAN; 100-300 msec) or Left Anterior Negativity (LAN; 300-500 msec) (see e.g., Kutas, Van Petten, & Kluender, 2006). However, neither in the present study nor in previous ERP studies from our lab in which syntactic violations were investigated (E)LAN effects were observed.

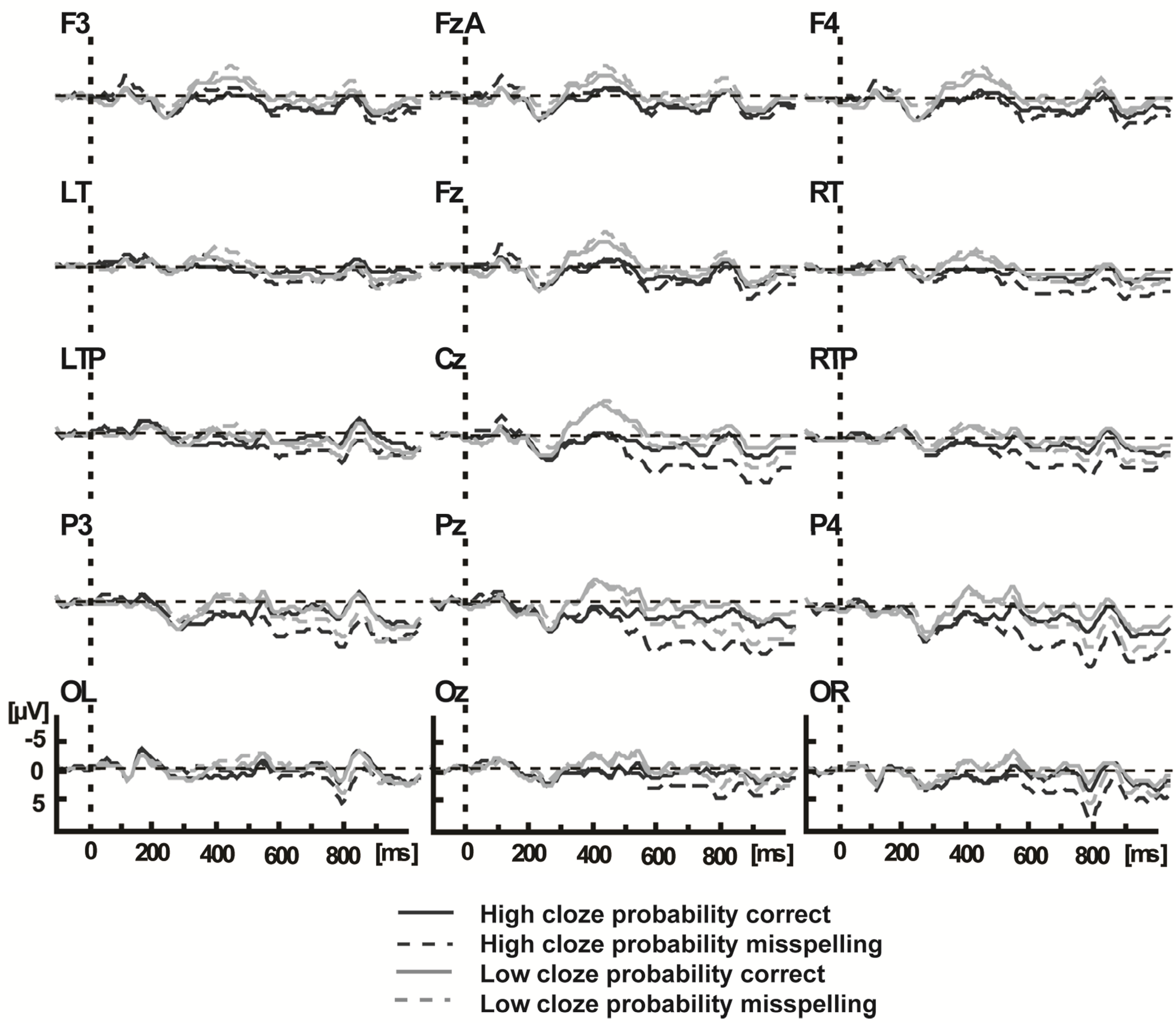

Figure 3. Grand-average ERP waveforms to the critical words for all midline and a subset of lateral sites, for all spelling conditions.

N400 cloze probability effect of words and misspellings

A standard cloze probability effect was found for both the misspelled and the correctly spelled words. The correctly spelled words revealed a main effect of Cloze probability for the midline sites [$F(1,27)=29.00$, $p<.001$] and for the lateral sites [$F(1,27)=18.49$, $p<.001$]. In addition, Cloze probability x Site interactions were present [midline sites: $F(4,24)=5.20$, $p<.01$, lateral sites: $F(4,24)=8.57$, $p<.001$]. For the lateral sites a Cloze probability x Region x Site interaction [$F(4,24)=4.92$, $p<.001$] and a Cloze probability x Hemisphere x Region x Site interaction [$F(4,24)=3.38$, $p<.05$] were present. Follow-up single site analyses confirmed a broadly distributed N400 effect for the low cloze probability correct condition at all midline and a subset of lateral sites (all ps.<.05, except F7A, F8A, F7, F8, LAT and T5).

Likewise, the analysis of the misspellings showed a main effect of Cloze probability for the midline sites [F(1,27)=51.17, p<.001] and for the lateral sites [F(1,27)=37.80 p<.001], and a Cloze probability x Site interaction for both [F(4,24)=6.95, p<.001 and F(4,24)=6.96, p<.001, respectively]. For the lateral sites interactions between Cloze probability x Hemisphere [F(1,27)=29.82, p<.001], Cloze probability x Region x Site [F(4,24)=3.69, p<.01] and Cloze probability x Hemisphere x Region x Site [F(4,24)=3.17, p<.05] were present. Single-site analyses yielded a broadly distributed N400 effect for the low cloze probability misspelling condition at all midline and a subset of lateral sites (all ps.<.05, except F7A, F7 and T5).

N400 effect within the high and low cloze probability conditions

No significant effects were found for the midline sites. The lateral analyses for the high cloze probability conditions indicated a Spelling x Hemisphere interaction [F(1,27)=19.50, p<.001] and a Spelling x Hemisphere x Region x Site interaction [F(4,24)=3.35, p<.05]. The interactions reflected that only at the left hemisphere N400 amplitude was larger (i.e., more negative going) for the high cloze probability misspelling compared to the high cloze probability correct condition at F7, LAT, LT, LTP, T5 and OL.

The lateral analysis for the low cloze probability conditions showed a main effect of Spelling [F(1,27)=7.70, p<.01], reflecting a broadly distributed N400 effect for the low cloze probability misspelling condition.[11]

[11] Newman and Connolly (2004) reported an N270 after pseudohomophones and orthographically unexpected words. They proposed that the amplitude of the N270 is modulated by mismatches between the orthographic input and the orthographic expectations elicited by the context. Therefore, following Newman and Connolly (2004) and Vissers et al. (2006) additional analyses were performed on the most negative peak in the 200-350 msec window. These analyses showed an effect of Cloze probability for the midline sites [F(1,27)=21.76, p<.00] and lateral sites [F(1,27)=11.71, p<.01], indicating that the amplitude of the N270 was larger for the low than the high cloze probability conditions. The lateral sites revealed a Cloze probability x Spelling interaction [F(1,27)=4.38, p<.05] and Cloze probability x Spelling x Hemisphere interaction [F(1,27)=4.99, p<.05]. Analyses of both hemispheres separately revealed a Cloze probability x Spelling interaction for the right hemisphere only [F(1,27)=7.25, p<.05]. Hence, separate analyses of the right hemisphere were performed for the two levels of cloze. This resulted in an effect of Spelling for the low cloze probability conditions only [F(1,27)=6.05, p<.05]. No interactions with Spelling were obtained. These results indicated a larger N270 amplitude for the low cloze probability misspelling compared to the low cloze probability correct condition across the right hemisphere. The study by Vissers et al. (2006) also showed a larger N270 amplitude to low cloze probability misspellings only. They propose that the misspellings in the high cloze probability condition might not be detected at this early stage due to an 'orthographic illusion' (see Vissers et al., 2006).

P600 window (500-800 msec)

Syntactic violations

For the syntactic data a main effect of Syntax [F(1,27)=9.60, p<.01] and a Syntax x Site interaction [F(4,24)=4.89, p<0.01] were found for the midline sites. This indicated that P600 amplitude was larger (i.e., more positive going) for the syntactically incorrect compared to the syntactically correct condition at central-posterior sites (Cz, Pz and Oz). At the lateral sites a main effect of Syntax [F(1,27)=9.87, p<.01] and a Syntax x Region interaction [F(1,27)=9.00, p<.01] were present. Separate analyses of the anterior and posterior region revealed a P600 effect for the syntactically incorrect condition over the posterior region only [F(1,27)=18.39, p<.001].

Spelling violations

For the spelling data main effects of Cloze probability and Spelling were found for the midline sites [F(1,27)=24.59, p<.001 and F(1,27)=7.83, p<0.01, respectively] and for the lateral sites [F(1,27)=15.08, p<.001 and F(1,27)=6.90, p<0.05, respectively]. This reflected that overall mean amplitudes were more positive for the high than the low cloze probability conditions and more positive for the misspellings than the correct words. Interactions of Cloze probability x Spelling were present for the midline sites [F(1,27)=5.28, p<0.05] and for the lateral sites [F(1,27)=7.67, p<0.01]. In addition, for the lateral sites a Cloze probability x Spelling x Hemisphere x Region interaction was present [F(1,27)=4.55, p<.05]. Separate analyses per quadrant indicated a Cloze probability x Spelling interaction for the left posterior [F(1,27)=6.39, p<.05] and right posterior quadrant [F(1,27)=6.73, p<.05]. These results revealed that at the midline and bilateral posterior regions the P600 effect to misspellings was larger in the high than the low cloze probability condition.

Separate analyses of the high and low cloze probability conditions confirmed that the mean P600 amplitude was larger for misspellings than corrects words in both. In the high cloze probability condition, at the midline sites a main effect of Spelling [F(1,27)=11.30, p<.01] and a Spelling x Site interaction [F(4,24)=10.59, p<.001] indicated that P600 amplitude was larger for the high cloze probability misspelling compared to the high cloze probability correct condition at Cz, Pz and Oz. For the lateral sites, a main effect of Spelling [F(1,27)=10.88, p<.01] and interactions between Spelling x Site

[F(4,24)=6.66, p<.001], Spelling x Hemisphere [F(1,27)=6.44, p<.05] and Spelling x Region [F(1,27)=16.50, p<.001] reflected that for the high cloze probability misspelling condition a P600 effect was present over all posterior sites (all ps<.05). In addition, for the latter condition a negativity was found at a single left frontal electrode (F7A).

For the low cloze probability condition a Spelling x Site interaction was found for the midline sites [F(4,24)=7.40, p<.001] and for the lateral sites [F(4,24)=4.32, p<.01]. For the lateral sites interactions between Spelling x Hemisphere [F(1,27)=5.53, p<.05], Spelling x Region [F(1,27)=14.85, p<.001] and Spelling x Region x Site [F(4,24)=7.37, p<.05] were present as well. These results showed that P600 amplitude was larger for the low cloze probability misspelling compared to the low cloze probability correct condition at a subset of posterior sites (Pz, Oz, LTP, P3, P3P, RTP, T6, P4, P4P and OR; ps<.05). As was the case for the high cloze probability misspelling condition, the low cloze probability misspelling condition showed a negativity at F7A.[12]

Topography of the P600 effects

To compare the scalp distributions of the P600 effect elicited by syntactic and spelling violations two additional MANOVAs were conducted. These MANOVAs included the critical factors Material (syntactic, high cloze probability spelling/low cloze probability spelling) and Acceptability (acceptable and unacceptable). Interactions between Material, Acceptability and Site, Hemisphere or Region would indicate the possibility of differences in scalp distribution between the two kinds of violations. If such an interaction was present we normalized the data according to the McCarthy and Wood (1985) procedure which equalizes the amplitude differences between conditions.[13]

When comparing the syntactic with the high cloze probability spelling materials no interactions were found for the midline sites. For the lateral sites there was an interaction of Material x Acceptability x Hemisphere [F(1,27)=8.64, p<.01] and a trend

[12] To determine whether the effects found in the N400 window could have caused the results in the P600 window, supplementary analyses were conducted in which the data were aligned between 400 and 500 msec. With these supplementary analyses, essentially the same results as with the original analyses were obtained. In particular, both high and low cloze probability misspelling conditions elicited a central-posterior distributed P600 effect compared to their correct controls, and this effect was larger in the high than in the low cloze probability conditions. These supplementary analyses reveal that the pattern of results for the P600 was not caused by differences in the preceding N400 window.

[13] In recent papers it is debated whether normalization should be used (Urbach & Kutas, 2002; Urbach & Kutas, 2006; Wilding, 2006). Therefore, we report both the results from the non-normalized and the normalized data when there is an interaction in the initial analysis.

for a Material x Acceptability x Region interaction (p=.06). However, separate analyses of the two hemispheres and regions did not reveal Material x Acceptability x Site interactions (all Fs<2). The analyses therefore did not reveal significant differences in the topography of the P600 effect to syntactic and high cloze probability spelling violations.

When comparing the syntactic with the low cloze probability spelling materials, no interactions were found for the midline and lateral sites. For the lateral sites, a trend was present for an interaction between Material x Acceptability x Hemisphere (p=.054), Material x Acceptability x Hemisphere x Site (p=.057), and Material x Acceptability x Region x Site (p=.06). To check whether these trends could point at differences in scalp topography the data were normalized. The lateral analysis on the normalized data yielded a trend for a Material x Acceptability x Hemisphere interaction (p=0.053). However, separate analyses per hemisphere failed to disclose significant Material x Acceptability x Site interactions (both Fs<2). These results therefore do not support that there are topographical differences in P600 effect between the syntactic and low cloze probability spelling violations.

Discussion

In the EEG experiment we compared the effects of representational conflict due to syntactic violations and misspellings. In addition, we tested our conflict strength manipulation of the misspelling material. We changed the low cloze probability condition of Vissers et al. (2006) to be sure that no conflicting representations could be present based on the sentence context.

First, in agreement with the previous literature, both the syntactic and the spelling violations elicited a central-posterior P600 effect. A comparison of the scalp distribution of these P600 effects did not show significant differences. These results are consistent with the assumption of the monitoring theory of language perception that qualitatively similar processes are involved in the processing of syntactic and spelling violations.

Second, in agreement with Vissers et al. (2006) a P600 effect was found to misspellings in high cloze probability sentences. In contrast, a P600 effect was now also present for misspellings in low cloze probability sentences. Our results indicated that the P600 effect to misspellings was modulated by the conflict strength manipulation because the P600 effect elicited by high cloze probability misspellings was larger compared to the P600 effect elicited by low cloze probability misspellings. These results call for an adjustment of the conclusions made by Vissers et al. (2006) that only misspellings in sentences in which the related correct word is highly expected elicit a strong enough conflict between competing representations and trigger a P600 effect. It seems that in addition to expectations generated by the sentence context, the word context (i.e., the orthography and phonology of the word) as such also has an effect. In the present low cloze probability condition, no specific expectations were generated by the sentence context. However, still a P600 effect to the low cloze probability misspellings was present, indicating that an expectation based upon the word context alone, could trigger a representational conflict of sufficient size.

A study that also reported a P600 modulation related to expectancy was the study by Coulson et al. (1998). They manipulated the proportion of sentences that contained a syntactic violation. Syntactic violations that were improbable to occur in a block (probability of 20%) elicited larger P600 amplitudes than probable syntactic violations (probability of 80%). Coulson et al. (1998) proposed that the differences in P600 amplitude reflect the way that individuals update their mental models of the environment which are governed by their expectations. A grammatical violation deviates from what is expected based on daily life, and therefore leads to updating of the mental model. However, although participants might expect a grammatical form by default, a probable syntactic violation block leads them to expect an ungrammatical form. In terms of conflict strength the amplitude decrease for the probable syntactic violations is due to a weaker conflict. Although participants come to expect an ungrammatical form, the expectation for a grammatical form is not completely absent leading to a smaller P600 amplitude.

fMRI experiment

Introduction

An fMRI experiment using the same stimuli as in the EEG experiment was conducted. The EEG experiment showed that the syntactic and spelling violations elicited similar

P600 effects. Therefore, we were interested to see whether the different representational conflicts would also elicit similar brain area activations, a possible candidate being the lIFG. Furthermore, the EEG experiment showed that the P600 effect to misspellings was modulated by the conflict strength. Therefore, we hypothesized that any brain area that is sensitive to the conflict strength manipulation should differentiate between high and low cloze probability misspellings as well.

Materials and methods

Participants, stimulus materials and procedure

In the fMRI experiment, 20 other participants that met the same criteria as the ones in the EEG experiment participated. Sixteen participants were included in the final analyses (12 women; mean age = 22.1 years; age range = 18 to 26 years). Four subjects were excluded because of excessive head movements or because they made too many errors on the comprehension questions.

The same materials and procedure as in the EEG experiment were used with the following exceptions: The participants lay in the scanner and saw the stimuli via a mirror attached to the head coil. Furthermore, in the fMRI experiment the length of the inter-trial interval, during which a fixation cross was shown, was jittered between 4300 and 6700 msec (mean 5500 msec), followed by a 500 msec blank screen. In addition, to avoid left hemisphere motor activation, participants were asked to respond to the content questions with the left index or middle fingers.

Between the first and the second run there was a short break in which the anatomical T1 images were acquired. Between the second and third run the participants were taken out of the scanner for a short break.

Data acquisition and analysis

The fMRI data were acquired on a 3T Siemens Trio scanner. The functional images were obtained using a T2*-weighted EPI-BOLD fMRI scan (TR = 2400 msec, TE = 30 msec, 80° flip angle). Thirty-five slices were acquired in an ascending order with a voxel size of 3.5x3.5x3.0 mm and a field of view of 224 mm. The anatomical images were obtained using a T1-weighted MP-RAGE GRAPPA sequence (TR = 2300 msec, TE=3.03 msec, 8° flip angle, 192 slices, voxel size = 1.0x1.0x1.0 mm, field of view = 256 mm).

The fMRI data were preprocessed and analysed using the SPM5 software (http://www.fil.ion.ucl.ac.uk/spm). The first five volumes of each participant were discarded to allow for T1 equilibration effects. The functional images were realigned, slice-time corrected, and each subjects' mean functional image was coregistered to the subjects' anatomical T1 image. Subsequently, the images were anatomically normalized to a T1 template image and smoothed with an 8 mm FWHM Gaussian kernel.

The data of the spelling and syntactic materials were analysed separately. At the first level, single-subjects analyses were conducted. The linear models of each subject included regressors that modelled the sentence conditions (syntactically correct and incorrect; high cloze probability correct and misspelling, low cloze probability correct and misspelling) from the critical word onwards to the end of the sentence. The correct filler sentences and the correct experimental sentence beginnings (until the word before the critical word) were included in a 'general correct' (GC) regressor. In addition, regressors were included for the inter-trial interval in which a fixation was shown (FIX) and for six realignment parameters describing head movements. The regressors were convolved with a canonical hemodynamic response function. For the second-level analysis, the contrast images from the first level were entered into a random effects group analysis.

Whole brain analysis

In the whole brain analysis of both the syntactic and spelling data we obtained the single-subject contrast images for all experimental conditions and GC relative to FIX. Differential effects of the experimental conditions were calculated at the second-level with a full factorial design for both the syntactic and the spelling data. The results of the analyses were thresholded at $p<.001$ (uncorrected). Cluster size was used as a test-statistic, and only activation clusters at a threshold of $p<.05$ (corrected) are reported. All local maxima are reported as MNI coordinates.

Region of interest specification

To test for possible material specific activation in the fMRI experiment, we selected regions of interest (ROIs) based on two different sets of studies. First, we conducted a meta-analysis of twelve neuroimaging studies that contained syntactic violations, and included an area as a ROI when three or more studies reported this area (see Table 3)[14]. Four ROIs were selected based on these studies: left inferior frontal gyrus (lIFG), right inferior frontal gyrus (rIFG), left posterior superior temporal gyrus (lPSTG), and anterior cingulate gyrus (ACG). The mean coordinates and mean distance of the local maxima to the mean coordinates were calculated. The radius of the ROIs was based on these mean distances, resulting in the following mean coordinates and spheres: lIFG [-52, 11, 21], 12 mm sphere; rIFG [52, 15, 23], 14 mm sphere; lPSTG [-58 -35 8], 10 mm sphere; ACG [-1, 8, 52], 9 mm sphere (see Figure 4 for a depiction of the ROIs).

Second, since at present few neuroimaging studies have been conducted using pseudohomophones, we based our ROIs for the spelling violations on a meta-analysis on pseudowords by Mechelli, Gorno-Tempini, and Price (2003). Three ROIs were selected based on this meta-analysis: left inferior temporal gyrus (lITG), lIFG, and right cerebellum. Again the mean coordinates and distance were calculated (lITG [-47, -62, -20], 9 mm sphere; lIFG [-45, 12, 14], 14 mm sphere; right cerebellum [18, -62, -39], 22 mm sphere) (see Figure 4).

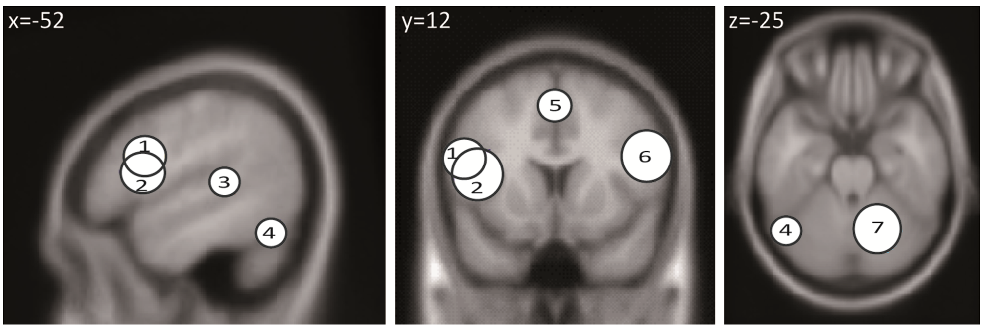

Figure 4. ROIs used in the present study, 1=$lIFG_{syn}$; 2=$lIFG_{spel}$; 3=lPSTG; 4=lITG; 5=ACG; 6=rIFG; 7=right cerebellum.

[14] Only nine studies are included in Table 3 because the other three (Indefrey, Hagoort, Herzog, Seitz, & Brown, 2001; Kuperberg, Holcomb, et al., 2003; Kuperberg et al., 2000) did not find activation in the ROIs and/or did not report coordinates.

Region of interest analysis

An ROI analysis on the syntactic and spelling data was performed in which all the regions were tested using the Marsbar toolbox for SPM (Brett, Anton, Valabregue, & Poline, 2002, http://marsbar.sourceforge.net). The lIFG region resulting from the syntactic studies ($lIFG_{syn}$) and the lIFG region resulting from the pseudoword studies ($lIFG_{spel}$) were tested in separate analyses because they showed some overlap.

A 2 x 6 repeated measures MANOVA was performed on the syntactic data, including the factor Syntax (correct, incorrect) and ROI ($lIFG_{syn/spel}$, rIFG, lPSTG, ACG, lITG and right cerebellum). For the spelling data a 2 x 2 x 6 repeated measures MANOVA was conducted, including the factor Spelling (correct and misspelling), Cloze probability (high and low) and ROI ($lIFG_{syn/spel}$, rIFG, lPSTG, ACG, lITG and right cerebellum). These MANOVAs were based on the contrast values that were obtained in the ROIs from the single-subject contrast images for the experimental conditions (syntactically correct, syntactically incorrect; high cloze probability correct, high cloze probability misspelling, low cloze probability correct and low cloze probability misspelling) with the inter-trial interval (FIX) as a baseline.

Results

Performance on the comprehension task

Mean error rate on the comprehension questions was 9.5% (syntactic part: 5.6%; misspelling part: 11.5%). Two participants were excluded from the analysis because they made more than 7 errors (25.9%) in total. The low error percentages indicate that the participants read the sentences attentively.

Whole brain analysis

Syntactic data

The results of the contrast syntactically correct > syntactically incorrect are listed in Table 4a. The clusters that were significantly stronger activated for the syntactically correct than syntactically incorrect condition included regions in the anterior and middle cingulate cortex and the right medial frontal gyrus. The contrast syntactically incorrect > syntactically correct yielded no significant results.

Table 3. MNI coordinates of the ROIs that were selected based on syntactic violation studies.

Study	Violation type	lIFG	rIFG	lPSTG	ACG
Cooke et al. (2006)	Inflection, word category, transitivity violations	[-61, 7, 26]	[48, 7, 35]		[4, 14, 53]
		[-44, 11, 27]	[48, 6, 44]		[-12, 6, 57]
		[-53, -2, 43]			[4, 6, 57]
Embick, Marantz, Miyashita, O'Neil, & Sakai (2000)	Word order violation	[-52, 10, 19]	[46, 17, 16]	[-59, -34, 9]	
Friederici, Rüschemeyer, Hahne, & Fiebach (2003)	Phrase structure violation			[-62, -42, 20]	
Kang, Constable, Gore, & Avrutin (1999)	Word category violation	[-51, 15, 14]			[0, 0, 44]
		[-45, 26, 6]			
Kuperberg et al. (2008)	Number agreement violation	[-49, 3, 8]		[-54, -21, -2]	
Meyer, Friederici, & Von Cramon (2000)	Phrase structure, number/gender/case agreement violations			[-56, -41, 5]	
Moro et al. (2001)	Word order, number agreement violations in pseudowordsentences		[59, 22, 10]		
			[61, 14, 14]		
			[51, 14, 14]		
			[59, 22, 19]		
Nichelli et al. (1995)	n.s.		[40, 15, 31]		[0, 16, 49]
Wartenburger et al. (2004)	Word order violation	[-60, 16, 18]			

Spelling data

In the whole brain analysis of the spelling data a comparison was made between the misspelled and correctly spelled conditions. The contrast correctly spelled > misspelled yielded no significant results. The results of the contrast misspelled > correctly spelled are listed in Table 4b. Regions that were significantly stronger activated for the misspelling conditions compared to the correctly spelled conditions included the right superior occipital gyrus, right superior parietal lobule, left cerebellum and left fusiform gyrus (see Figure 5a).

In addition, a comparison was made between the high and low cloze probability conditions. In Table 4c. the results of the high cloze probability > low cloze probability contrast are listed. The left and right IPL showed a significantly stronger activation for the high cloze probability conditions (see Figure 5b). No significant results were obtained with the low cloze probability > high cloze probability contrast.

No significant results were obtained for the interaction of Spelling x Cloze probability.

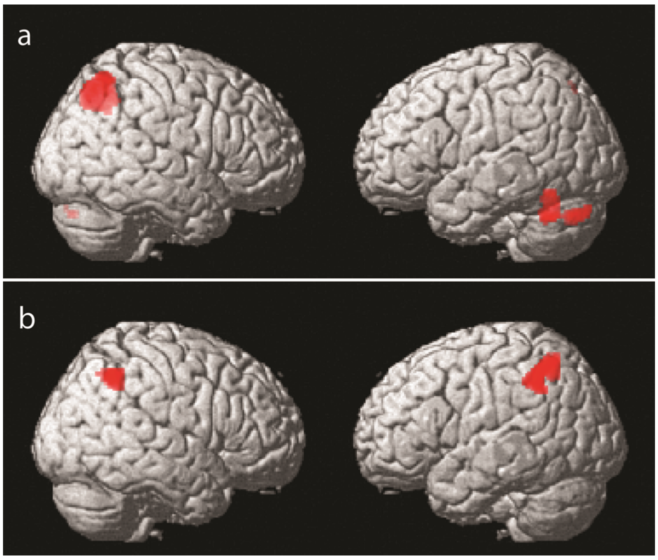

Figure 5. (a) Significant activation clusters from the whole brain analysis for the misspelled relative to the correctly spelled condition. (b) Significant activation clusters from the whole brain analysis for the high cloze probability relative to the low cloze probability condition.

Table 4. Significant clusters at the whole brain level.

Region	BA	Cluster size	Voxel T value	x	y	z
a. syntactically correct > syntactically incorrect						
Anterior cingulate cortex	24	631	5.28	2	38	4
	25			6	18	-4
				-2	18	-2
Right middle cingulate cortex	9	323	4.94	12	30	36
Right middle frontal gyrus				24	32	38
				28	26	32
b. misspelled > correctly spelled						
Right superior occipital gyrus	19	476	4.62	28	-68	48
Right superior parietal lobule	7		4.57	34	-62	54
Left cerebellum		344	4.28	-32	-74	-32
			3.68	-48	-56	-34
Left fusiform gyrus	37		3.62	-48	-58	-22
c. high > low cloze probability						
lIPL	40	395	4.11	-42	-60	54
			3.89	-56	-48	42
rIPL	40	257	3.86	48	-54	44
			3.67	38	-58	46

Note: The table shows all clusters at a significance level of p<.05 corrected at the cluster level (thresholded at p<.001 uncorrected). All local maxima are reported as MNI coordinates.

Region of interest analysis

Syntactic data

The analysis including $lIFG_{syn}$ revealed a Syntax x ROI interaction [$F(5,11) = 6.30$, $p<.01$]. Follow-up analyses showed a main effect of Syntax in $lIFG_{syn}$ only [$T(15) = -3.49$, $p<.01$], indicating that the syntactically incorrect condition elicited significantly more activation in lIFG than the syntactically correct condition (mean contrast value syntactically incorrect=0.73, syntactically correct=0.51, see figure 6).

When using $lIFG_{spel}$ instead of $lIFG_{syn}$ in the analysis the same results were obtained; significant results were obtained for $lIFG_{spel}$ only [$T(15) = -2.78$, $p<.05$] (mean contrast value syntactically incorrect=0.43, syntactically correct=0.31, see figure 6).

Spelling data

The analysis revealed a main effect of Spelling [$F(1,15) = 15.39$, $p<.01$] and a Spelling x ROI interaction [$F(5,11) = 3.92$, $p<.05$]. No main effect of Cloze probability or interaction with this factor was found. Follow-up analyses showed that all ROIs except lPSTG showed a main effect of Spelling (all ps<.05). This indicated that in $lIFG_{spel}$, rIFG, lITG, ACG, and right cerebellum the misspelling condition elicited significantly more activation than the correctly spelled condition. When using $lIFG_{syn}$ in the analysis the same results were obtained; all ROIs except lPSTG showed a main effect of Spelling (all ps<.05). Figure 6 gives an overview of the mean contrast values per ROI.

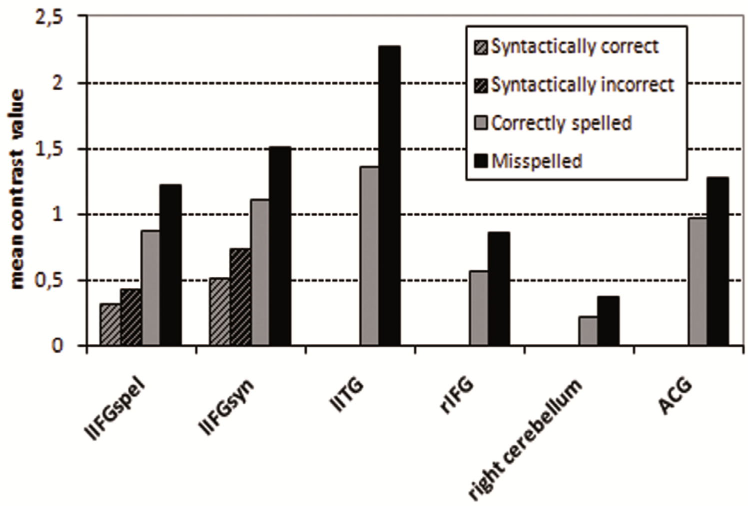

Figure 6. Mean contrast values per ROI for the syntactically correct and incorrect condition, and the correctly spelled and misspelled condition.

Discussion

We investigated whether the representational conflicts elicited by syntactic and spelling violations would generate co-localized activation. In addition, we were interested whether the effects of conflict strength manipulation on the processing of spelling violations that were observed in the EEG experiment would also modulate the hemodynamic response in the fMRI.

The results from the ROI analyses showed that both the syntactic and the spelling violations elicited stronger activation in the lIFG relative to their controls. The high and low cloze probability misspellings did not elicit differential activation in this area, indicating no modulation by conflict strength. In addition to the lIFG activation, the spelling violations elicited stronger activation compared to their correct controls in the rIFG, right superior occipital and parietal areas, right and left cerebellum, lITG/left fusiform gyrus, and ACG. Again, the activation in these areas was not modulated by conflict strength. However, the activation was specific to the spelling violations; the syntactic violations did not elicit any other additional activations than the activation in lIFG. In the general discussion we will elaborate on these findings.

Although the ROI analyses revealed significant activation in the lIFG for both types of violations, the whole brain analyses did not. Previous studies, however, did find lIFG modulation at the whole brain level when contrasting for example syntactically incorrect with syntactically correct stimuli (see e.g., table 3). The fact that we did not find lIFG activation at the whole brain level could be because our experiment did not involve an explicit judgment task, which might increase the underlying neural response. For example, all studies that were included in our meta-analysis of syntactic violation studies that reported lIFG activation at the whole brain level used such a task, except from the study by Kang et al. (1999). We explicitly chose not to use a judgment task, to stay as close as possible to 'normal reading' and because this type of task has been shown to modulate the P600 (e.g., Kuperberg, 2007).

General discussion

The present study tried to further connect the existing literature on the involvement of cognitive control in dealing with representational conflicts to the literature on error monitoring in language perception. To this end, an EEG and fMRI experiment were conducted investigating representational conflicts created by syntactic and spelling violations. These violations elicited similar ERP responses in previous studies and we were interested whether they would create co-localized activation in the fMRI. The conflict strength created by misspellings was manipulated as well to address the question whether this would modulate both the P600 component and the hemodynamic response. We will first discuss the results of the EEG experiment, then go into the results of the fMRI experiment, and end with a discussion of the differences in findings.

EEG findings

Previous EEG studies found that syntactic and non-syntactic conflicts elicited positivities with very similar scalp distributions. The present EEG experiment added support to these findings by showing within subjects that both the syntactic and spelling violations elicited a similarly distributed central-posterior P600 effect compared to their correct controls. This suggests that similar processes are involved in the processing of syntactic and spelling violations.

As mentioned briefly in the general introduction, the functional significance of the P600 effect is debated. The dominant view has been that it indexes syntactic processing. For example, it has been proposed that the P600 effect reflects syntactic reanalysis or repair (e.g., Friederici et al., 1996) or syntactic integration difficulties (e.g., Kaan et al., 2000). Hagoort (2003, 2009) interpreted the P600 effect in light of the Unification Model as proposed by Vosse and Kempen (2000). According to this model every incoming word is associated with a lexical frame (i.e., an elementary syntactic tree) that is retrieved from memory. These frames incrementally enter a unification space where they are bound together into a phrasal configuration. This process is dynamic, because due to competing alternative binding candidates the strength of the unification links vary over time until a stable configuration is reached. Hagoort (2003, 2009) proposed that the P600 reflects the formation of unification links. The P600 amplitude is thought to be related to the time that is needed to form unification links of sufficient strength, which is influenced by syntactic complexity, by syntactic ambiguity, and by semantic influences.

A different explanation of the P600 effect was given by Kuperberg (2007). She proposed that comprehension of verb-argument relationships within sentences proceeds along at least two interactive processing streams. In the first stream the evolving representation of meaning is evaluated and compared with patterns of relationships that are prestored within semantic memory. The second stream is a combinatorial stream that involves combining words based on multiple rule-like constraints, including morphosyntactic and thematic-semantic constraints, to build up a propositional meaning. According to this account, the P600 effect reflects a continued analysis within the combinatorial stream triggered by a conflict between its output and the output of the semantic memory-based stream.

Although these accounts of the functional significance of the P600 effect, do not predict an effect for spelling violations in and of themselves, they cannot be excluded completely. For example, Kuperberg (2007, p.41) leaves open the question of whether an orthographic processing stream exists. If an orthographic processing stream exists, a P600 effect elicited by a spelling violation could result from a continued analysis within such a stream. From a syntactic or a unification perspective, spelling violations could affect syntactic processing or influence the time needed to establish sufficiently strong unification links. However, we think a syntactic or a unification account is less plausible in the present study because we used pseudohomophones that could easily be traced back to the words from which they were derived. Therefore, we think it is less likely that they would make syntactic processing more difficult. It is also less likely that the time needed to establish sufficiently strong unification links is affected. Since the correct word can easily be traced back, the lexical frames should be accessible and unification should be possible. If it were the case that the pseudohomophones do not lead to the retrieval of lexical frames in memory, we think the Unification Model would predict an (E)LAN. Hagoort (2003, 2009) proposed that an (E)LAN results from a binding failure when there is no matching category node. If a pseudohomophone is not associated with a lexical frame, an NP node in the syntactic tree of the phrasal configuration cannot be filled.

The monitoring theory of language perception can account for the finding that both syntactic and spelling violations trigger a similar P600 effect. According to this theory a P600 is elicited when there is a strong representational conflict between an expected and observed element that triggers reprocessing of the input to check for possible processing errors (e.g., Van de Meerendonk et al., 2009). Such a representational conflict is created by both syntactic and spelling violations. For the syntactic violations a conflict arises between an expected grammatical form and an observed ungrammatical form. The spelling violations create a conflict between an expected correctly spelled word and the observation of an incorrectly spelled word.

The monitoring theory assumes that only representational conflicts that are sufficiently strong should trigger reprocessing of the input and elicit a P600. The present EEG experiment manipulated conflict strength by varying expectancy based on the sentence context in the spelling materials. The results indicated that the P600 effect was larger for high cloze probability misspellings than low cloze probability misspellings. Our finding of a modulation by conflict strength reinforces the importance of the conflict concept, a notion that is present in other theories of the P600 component as well (see Hagoort, Baggio, & Willems, 2009; Kuperberg, 2007).

fMRI findings

The fMRI results showed that syntactic and spelling violations both increased activation in the lIFG compared to their correct controls. This corresponds to the findings of Embick et al. (2000) who compared syntactic word order violations and spelling errors in sentences (e.g., *paper* written as *papger*) to a control condition in which rows of coloured letters were shown. In this study, the participants' task was to indicate whether one or two errors were present in the sentences, or whether one or two matches (i.e., a colour-letter combination) occurred in the control condition. Their results also showed that both syntactic and spelling violations elicited increased activation in the lIFG compared to their control condition.

At present, various accounts on the role of the lIFG in language processing exist. For example, increased activation in the lIFG might reflect the computation of syntactic movement of elements in a sentence (e.g., Grodzinsky & Friederici, 2006). Another proposal is that the lIFG activation reflects increased demands on syntactic working memory due to the temporal maintenance of unintegrated syntactic information (e.g., Fiebach, Schlesewsky, Lohmann, Von Cramon, & Friederici, 2005). Hagoort (2005) proposed that the lIFG is involved in the unification of lexical elements that are retrieved mainly from the temporal lobes. According to this proposal the lIFG is involved in the syntactic as well as semantic and phonological unification of lexical elements, with a certain level of specialization in different subregions. These different accounts, however, have difficulty in explaining the co-localized lIFG activation for syntactic and spelling violations. The syntactic accounts would have to assume that misspellings affected the syntactic processing, which we think again is less likely since we used pseudohomophones. Unification should not be affected either, because pseudohomophones should not lead to difficulties with the formation of syntactic, semantic or phonological representations.

Novick et al. (2005) proposed that the lIFG is involved in implementing cognitive control to resolve representational conflicts (see also, e.g., Thompson-Schill et al., 2005; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997). Instead of reflecting a language specific process, it is thought that the process in the lIFG reflects a general conflict resolution mechanism. This account can explain the finding of co-localized lIFG activation for syntactic and spelling violations. Both types of violations create a representational conflict, and when such a conflict is present, the lIFG is thought to guide the neural activity in the appropriate pathways to prevent misinterpretations (e.g., Miller & Cohen, 2001).

Since our EEG results showed a sensitivity to the conflict strength manipulation, we hypothesized that any brain area that is sensitive to this manipulation should differentiate between high and low cloze probability misspellings as well. However, our fMRI results did not show such a differential effect in any brain region, indicating that the hemodynamic response was not modulated by conflict strength. January et al. (2009) also manipulated conflict strength between competing representations in an fMRI study. This was done by using different pairings of pictures and syntactically ambiguous sentences. Hereby, they created a weak (syntactically unambiguous sentences), medium and strong conflict condition. The conflict increased due to the fact that the pictures increasingly supported a less preferred interpretation of the ambiguous sentence (see January et al., 2009 for the specific details). Their results showed a significantly stronger activation in the lIFG for the strong compared to the weak conflict condition only. This result could indicate that two conditions that both create a representational conflict but that differ in their actual conflict strength can differentially activate the lIFG. However, it is unclear whether the weak conflict condition would also show differential effects in the lIFG compared to a no-conflict condition, since this was not tested. In addition, because the conflict manipulation that was used by January et al. (2009) is very different from the manipulation in the present study, it is not clear how their results should be mapped onto the present ones.

In addition to increased activation in the lIFG, the spelling violations also showed increased activation in more posterior areas when compared to their correct controls. These activations could reflect the actual (re)processing of the spelling violations. For example, the lITG/left fusiform gyrus closely corresponded to the visual word form area

(VWFA), an area which is thought to compute structural representations of words from abstract letter representations (e.g., Dehaene, Le Clec'H, Poline, Le Bihan, & Cohen, 2002). It is likely that upon encountering a spelling violation, (re)processing of the visual word form is done, and as indicated by our meta-analysis several studies have found this area to be more activated by pseudowords than words (see Mechelli et al., 2003). Furthermore, the activation that was found in the right occipital area might be related to some extra visual processing of the spelling violation. In contrast, an area that could be involved not in the (re)processing of the spelling violations as such but in conflict processing is the ACG. The ACG has been implicated in conflict detection and it has been suggested that it sends this information to frontal brain areas (e.g., Yeung et al., 2004). Note, however, that we do not find a modulation of the hemodynamic response depending on conflict strength in this region either.

For the syntactic violations, besides the increased activation in lIFG, we did not find any other additional activation. An area that is also often reported to show increased activation to syntactic violations is the lPSTG. First, it could be that our syntactic violations did not elicit a detectable response in the lPSTG because participants were not asked to judge grammatical acceptability of the sentences. All studies that were included in our meta-analysis conducted such a judgment, except the study by Kang et al. (1999) which also did not report activation in the lPSTG. Second, it could be that no lPSTG activation was detected because number agreement violations are relatively subtle compared to other types of violations, like word category violations. Kuperberg et al. (2008), however, did find lPSTG activation to number agreement violations.

Differences EEG and fMRI findings

It is important to note that we do not want to infer that the lIFG is the underlying neural source of the P600 component. One has to be cautious with such an interpretation because ERP and fMRI measurements capture neural responses at very different time scales. While ERPs allow for the detection of neural responses to critical words, the hemodynamic responses in the fMRI also reflect additional processes that occur after the critical words.

This difference in temporal resolution between ERP and fMRI measurements might explain why our conflict strength manipulation modulated the P600 but did not affect the hemodynamic response. Since fMRI measurements are temporally less sensitive than ERPs this could have resulted in a null finding for the conflict strength manipulation. In general, null results have to be interpreted cautiously, and they leave open the possibility that the hemodynamic response can be modulated by conflict strength.

Despite of this, we would like to suggest as a post-hoc explanation, that the ERP and fMRI measurements might capture different parts of the monitoring process. Whereas the P600 amplitude could primarily be related to the strength of the conflict, the hemodynamic response which was not modulated by conflict strength, could indicate the presence of reprocessing. Reprocessing is thought to occur when a conflict is of sufficient size, but would be identical for spelling violations in the high and low cloze probability conditions. This seems plausible, since the violations were identical in both conditions; only one letter was changed compared to the correctly spelled words. This does not mean that differences in the degree of reprocessing could not exist. If we would have different degrees of ill-formedness, contrasting for example one-letter-changed-misspellings with misspellings in which more letters are changed, this might result in differences in the amount of reprocessing. It is therefore assumed that the degree of reprocessing is not proportional to the degree of conflict (the conflict just needs to pass a certain ‘threshold’ to trigger reprocessing), but rather to the degree of ill-formedness of the encountered word.

Under this post-hoc hypothesis, the lIFG would guide the reprocessing of the unexpected representation by guiding activation in more posterior areas (e.g., the lITG/left fusiform gyrus). This is somewhat different from the proposal by Novick et al. (2005) regarding the implementation of cognitive control by the lIFG for conflict resolution in garden-path sentences. To prevent misinterpretations in garden-path sentences, Novick et al. (2005) proposed that selecting the relevant parse involved both the suppression of the initially expected but irrelevant parse and the recovery of the unexpected but relevant parse from all the information present. Our data, however, seem to suggest that the P600 amplitude modulation is related to the suppression of the expected representation, whereas the lIFG activity may correspond to the guidance of the reprocessing (recovery) of the unexpected representation (i.e., the violation) only. The finding that there is a larger P600 amplitude in the high relative to the low cloze probability misspellings, could reflect that more suppression of the expected representation is needed in the high cloze probability condition for which this representation is stronger. This would fit with previous proposals that positivities in the EEG could indicate inhibition of cortical neuronal networks (e.g., Coenen, 1995; Rockstroh, Müller, Cohen, & Elbet, 1992; Rockstroh et al., 1996). However, it should be noted that even if the amplitude difference of the P600 in the present study is related to the amount of suppression this does not exclude that the process underlying the P600 does also encompasses some reprocessing.

The possibility that the ERP and fMRI measurements capture different parts of the monitoring process could also explain why we found similarly distributed P600 effects to syntactic and spelling violations, while the hemodynamic response to spelling violations showed that additional regions were engaged. If the P600 effect would reflect an aspect of conflict processing (e.g., suppression of the expected representation) we suppose this process to be similar for syntactic and spelling violations. In contrast, if as proposed above, the hemodynamic activation would reflect the reprocessing, this might involve brain regions more specific to spelling violations (e.g., the lITG/left fusiform gyrus) than to syntactic violations and vice versa.

Conclusion

To conclude, the present study further explored representational conflicts underlying the detection and reprocessing of errors in language perception. In accordance with the monitoring theory of language perception, our results show that conflicts elicited by syntactic and spelling violations trigger similar P600 effects, which can be modulated by conflict strength. In addition, the finding of increased lIFG activation for both violation types connects the existing literature of the involvement of lIFG in dealing with representational conflicts to the literature on error monitoring in language perception.

Acknowledgments

Portions of this research were presented at the 17th Annual Meeting of the Cognitive Neuroscience Society in Montréal, 2010, and at the 7th Forum of European Neuroscience in Amsterdam, 2010. We thank two anonymous reviewers for their helpful comments on previous versions of this article. We are also grateful to the technical group of the Donders Institute for Brain Cognition and Behaviour for their support.

Chapter 5

Not only syntactic and semantic anomalies but also word degradation co-localize with the Stroop task in Broca's area

This chapter has been submitted in an adapted version as:
Van de Meerendonk, N., Rueschemeyer, S-A., & Kolk, H.H.J. (submitted). Not only syntactic and semantic anomalies but also word degradation co-localize with the Stroop task in Broca's area.

Abstract

The role of the prefrontal cortex, in particular the left inferior frontal gyrus (lIFG), has been studied extensively in various cognitive domains. Recently, a unifying account was proposed to explain the common role of the lIFG in supporting cognitive processing in different domains such as language and cognitive control. Specifically, it has been proposed that the lIFG is involved in general conflict resolution: when multiple representations compete, the lIFG implements cognitive control to bias attention towards one of the representations. This general mechanism is relevant for multiple higher-level cognitive domains. The present study further investigated this proposal of a general conflict resolution mechanism in the lIFG in relation to errors in language perception. To this end, an fMRI study was conducted in which the same group of participants read sentences containing syntactic agreement violations and violations of plausibility. In addition they took part in a Stroop task to localize cognitive control processes. Furthermore, to investigate whether conflicting representations are required for lIFG engagement, or whether other cognitively demanding inputs can signal that control adjustments are needed as well, a visual degradation condition was included in which no conflict between competing representations was assumed to be present. Both the violation conditions and the visual degradation condition elicited co-localized lIFG activation with the Stroop conflict. These results may indicate that the lIFG implements control adjustments to resolve situations in which extra attention is needed more generally. Next to biasing attention to resolve representational conflicts, the lIFG may also adjust control to compensate for a temporary lack of bottom-up information.

Introduction

Many studies on language perception continue to approach language from a relatively modular perspective. This is surprising, as language processing is a tremendously high-level cognitive ability which undoubtedly recruits abilities from seemingly unrelated cognitive domains. One of these domains is that of cognitive control. Cognitive control processes are the regulative processes that ensure goal-directed behavior. An aspect of cognitive control is monitoring, a process that evaluates the demands for control (e.g., McGuire et al., 1996; Stuss & Benson, 1986). One of the ways in which these demands for control can be assessed is by monitoring for conflicts in information processing (e.g., Botvinick et al., 2001). Conflicts occur when there is a mismatch between what we intend or expect and what we do or observe. The detection of such a mismatch leads to compensatory adjustments in the involved processing pathways. In general, the prefrontal cortex is thought to be involved in this control mechanism by biasing neural activity in these pathways (e.g., Miller & Cohen, 2001). Often mismatches have been studied in the action domain (for reviews see e.g., Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004; Yeung et al., 2004), but in language perception mismatches can occur as well. For example, we sometimes misread a word in a text and wonder whether we read it correctly. In this example there is a conflict between the word we expected and the word that we observed. The present study shows that cognitive control is needed to resolve these 'representational conflicts', in which we are dealing with two incompatible representations. In addition, the study addresses the question of whether such conflicts are necessary to engage control processes, or whether other conditions can signal the need for adjustments in control as well.

A classic cognitive control task to study compensatory adjustments to conflicts is the Stroop task (Stroop, 1935). In this task participants are instructed to name the ink color of a word and ignore the meaning of the printed word that also denotes a color. In the incongruent condition the ink color to be named differs from the printed color word (e.g., *green* printed in red ink), thereby creating a conflict. To bias attention towards the task-relevant information (i.e., the ink color) instead of the task-irrelevant information (i.e., the meaning of the printed word) cognitive control is needed. The posterior part of the left inferior frontal gyrus (Brodmann's area (BA) 44 and 45, henceforth indicated as lIFG) has been found to be activated by these incongruent Stroop trials, and this area is thought to implement compensatory adjustments in control (e.g., see Milham et al., 2003; Nee et al., 2007; Novick et al., 2005).

Within the language domain the lIFG has been referred to as Broca's area, and a well-known example of language conflict that has been found to activate this region is the case of garden-path sentences. Garden-path sentences are sentences that are locally ambiguous and have a preferred parse (e.g., 'The broker persuaded to sell the stock…'). These sentences therefore create a temporary misinterpretation, due to a conflict between the preferred analysis and the actual parse that needs an alternative analysis (e.g., Mason et al., 2003; Osterhout & Holcomb, 1992). Traditionally, Broca's area has been implicated in sentence processing, more specifically syntactic processing, since patients with Broca's aphasia show agrammatic production and have difficulties with comprehending syntactically complex sentences (e.g., Goodglass & Berko, 1960; Grodzinsky, 2000) – although it is now known that a lesion to Broca's area does not necessarily lead to Broca's aphasia (e.g., Dronkers, Wilkins, Van Valin Jr, Redfern, & Jaeger, 2004). In line with this traditional view, various studies have attributed activation in the lIFG to some form of syntactic processing. For instance, it has been proposed that increased activation in this area might reflect the computation of syntactic movement of elements in a sentence (e.g., Grodzinsky, 2000; Grodzinsky & Santi, 2008), or the computation of hierarchical syntactic structures (in particular in BA 44; e.g., Bahlmann, Schubotz, & Friederici, 2008; Friederici, Makuuchi, & Bahlmann, 2009). Another proposal is that the lIFG (BA 44 specifically) plays a critical role when demands on syntactic working memory increase due to temporal maintenance of unintegrated syntactic information (Fiebach et al., 2005). Hagoort (2005) broadened this working memory perspective by stipulating that not only syntactic but also phonological and semantic elements have to be kept available while single words are unified (i.e., integrated) into larger structures. This process of 'unification' is thought to occur in the lIFG (encompassing BA 44/45/47, and probably the ventral part of BA 6), with a certain level of specialization in different subregions for the integration of syntactic, phonological and semantic elements.

These various proposals, however, do not consider the results from the cognitive control literature, which indicate posterior lIFG activation in various tasks that do not require syntactic or language-specific processing (e.g., Stroop task (e.g., Milham et al., 2003); verb generation task (e.g., Thompson-Schill et al., 1997); working memory task (e.g., Jonides, Smith, Marshuetz, Koeppe, & Reuter-Lorenz, 1998)). Novick et al. (2005) offered a unifying account for the finding of lIFG activation in both the psycholinguistic and cognitive control literature. They proposed that the lIFG is involved in general conflict resolution. When there is a conflict between multiple competing representations, the lIFG implements cognitive control to bias activation towards one of the representations. Analogous to conflict resolution in the Stroop task, recovering from garden-path sentences requires the lIFG to make compensatory adjustments in control and bias attention towards the relevant parse (see also, e.g., Thompson-Schill et al., 2005; Thompson-Schill et al., 1997). A recent fMRI study by January et al. (2009) compared the activation in lIFG elicited by representational conflict in the Stroop task and representational conflict arising from ambiguous sentences within the same group of participants. The results showed co-localized activation within the lIFG for both types of conflict, supporting the proposal of a shared conflict resolution mechanism.

A recent study by Van de Meerendonk et al. (2011) connected this proposal of a general conflict resolution mechanism in lIFG to error monitoring in language perception. As in garden-path sentences and the Stroop task, a conflict between competing representations is assumed to be present for various types of errors in language perception, like semantic and syntactic violations, spelling errors and picture-sentence mismatches (for reviews see Kuperberg, 2007; Van de Meerendonk et al., 2009). The monitoring theory of language perception proposes that a strong mismatch between an expected and observed linguistic element induces a conflict, which elicits reprocessing of the input to check for possible processing errors. In various EEG studies, this process has been linked to the P600 component (for reviews see Kolk & Chwilla, 2007; Van de Meerendonk et al., 2009). Van de Meerendonk et al. (2011) investigated the representational conflicts elicited by syntactic agreement violations and spelling violations in an fMRI study within the same group of participants. In support of the proposal of a general conflict resolution mechanism in lIFG, the results showed co-localized increased activation in the lIFG for both types of representational conflict.

The aim of the present study was twofold. First, we wanted to further investigate the proposal of a general conflict resolution mechanism in lIFG in relation to representational conflicts arising from errors in language perception. The question was whether we could also find evidence – as January et al. (2009) reported in the case of syntactically ambiguous sentences – for a generalization of conflict resolution in a cognitive control task to conflict resolution for errors in language perception. To this end, we conducted an fMRI study in which participants read sentences that contained syntactic agreement violations and sentences that contained plausibility violations (see Table 1). In addition, the participants performed a Stroop task, to localize the part within the lIFG (BA 44/45) that shows increased activation to incongruent trials which elicit a representational conflict. In agreement with January et al. (2009), we determined this part of the lIFG for each individual participant, and investigated its sensitivity to representational conflicts arising from syntactic and semantic anomalies.

Based on the proposal of a general conflict resolution mechanism in lIFG, we predicted that both the syntactic agreement violations and the plausibility violations should elicit increased activation in the lIFG region that was determined from the Stroop task. Previous studies have indicated that different subregions in the lIFG could be involved with specific language processes. For instance, a meta-analysis by Bookheimer (2002) showed a division for syntactic (BA 44/45), semantic (BA 45/47) and phonological processing (BA 6/44). Hence, it is possible that a specialization exists within the lIFG for different types of linguistic conflict (e.g., arising from syntactic or plausibility violations). Such meta-analyses, however, are based on multiple studies that involved different tasks across various participants. In contrast, in the present study, one group of participants performed a single task for the sentence conditions: they carefully read a series of sentences containing various kinds of violations. The focus of the present study was on the lIFG region that was found active in the Stroop task for each individual participant, and we examined whether different types of representational conflicts elicited by perceptual language errors showed co-localized activation in this region.

The second aim of the present study was to investigate the necessity of conflicting representations for lIFG engagement. It has been generally accepted that monitoring for conflicts in information processing is one of the ways to assess the demands for control. However, other cognitively demanding inputs might also signal that control adjustments are required (e.g., Botvinick et al., 2001). A good example of such a demanding input in visual language perception is words that are difficult to read. For instance, imagine trying to read a prescription from your doctor who has very poor handwriting. To identify what the doctor has written down, extra attention needs to be allocated. This could indicate that, besides conflicts between expected and observed representations, a lack of bottom-up information might also signal that control adjustments are needed. Therefore, in the present study we added a visual degradation condition, which consisted of plausible sentences with no particular expectation for a certain word, in which the critical word could either be degraded or not. For this condition it is assumed that no conflict between an expected and encountered representation occurs, since no representation can be formed based on expectations, and the critical word, though difficult to read, does not contain an error of any kind. However, because the word is difficult to read, it can still be assumed that compensatory control adjustments are needed to identify the correct word, and this could involve the lIFG. In their comparison of the activation patterns of different cognitive demands (i.e., response conflict, task novelty, working memory and perceptual difficulty), Duncan and Owen (2000) showed that much the same regions of the prefrontal cortex, including lIFG, were activated. Therefore, they suggested that a specific network in prefrontal cortex is recruited by increases in demands to solve diverse cognitive problems. This proposal is in line with what Kahneman (1973) has referred to as *mental effort*, which is recruited when increasing demands require the allocation of extra attention.

To recapitulate, we hypothesize that the proposal of the involvement of lIFG in implementing cognitive control to resolve representational conflict would be strengthened if co-localized lIFG activation is found for the conflicts elicited by the Stroop task and syntactic and plausibility violations. If, in addition, the visual degradation condition shows co-localized lIFG activation as well, this could indicate that a conflict between competing representations is not necessary to elicit lIFG involvement. The lIFG might then still be involved in biasing attention, but it would serve not only to resolve representational conflicts, but also to compensate for a temporary lack of bottom-up information.

Materials and methods

Participants

Twenty-seven healthy right-handed native speakers of Dutch participated in the experiment. Twenty-four participants were included in the final analyses (19 women;

mean age=20,2 years; age range=18 to 24 years). Three participants were excluded because of excessive head movements or because they made too many errors on the comprehension questions (see below). All participants had normal or corrected-to-normal vision, had no language disability, and had no psychological or neurological impairment. The study was approved by the local ethics committee. Written informed consent was obtained prior to participation and participants were paid or received course credit.

Stimulus materials and procedure

The following paragraphs give an overview of the stimulus materials and procedures that were used in the present study. First, the stimulus materials of the three types of sentence conditions (plausibility, syntactic and visual degradation), which were each presented in a separate block, will be described. This description of the sentence materials will be followed by their corresponding experimental procedure. Second, the stimulus materials and procedure of the Stroop task will be explained.

Sentence conditions – plausibility materials

Ninety-nine sentence contexts were taken from a previous study with some minor changes (Van de Meerendonk et al., 2010) and 79 new sentence contexts were constructed in which a word from a certain category was highly expected. The expectancy was created by giving two exemplars of a certain category (e.g., ‘The eye consisting of among other things a pupil, iris and …’). The critical word that complemented the sentence context could be plausible, mildly implausible or deeply implausible, resulting in three conditions for each sentence context (see Table 1 for an example, and Appendix 3 of this thesis).

These 178 sentence contexts were tested in a plausibility judgment task with 42 participants (33 women; mean age = 20.5 years; age range = 18 to 26 years). In this task, the sentences were given up to the critical word, and the participants had to rate the plausibility of the sentences on a scale from 1 (very implausible) to 5 (very plausible). Three lists were created and the three sentence conditions were counterbalanced across lists, such that each participant saw each sentence context only once. An equal amount of participants was tested for each list (i.e., 14 participants per list). From this plausibility judgment task 162 experimental sentence contexts were selected. The mean plausibility rating for the plausible, mildly implausible and deeply implausible condition was 4.9, 3.1 and 1.1 respectively. An ANOVA indicated that these differences in plausibility were reliable across the three conditions ($p<.0001$). Follow-up pairwise comparisons between the three plausibility conditions revealed that ratings for the plausible sentences differed significantly from the ratings for the mildly and the deeply implausible sentences (both $ps<.0001$). Furthermore, these analyses revealed a significant difference between the ratings of the mildly and deeply implausible sentences ($p<.0001$).

Table 1. Example of the plausibility and syntactic conditions

Condition	Sentence
Plausibility	
plausible	Het oog bestaande uit onder andere een pupil, iris en netvlies is erg gevoelig.
	(The eye consisting of among other things a pupil, iris and retina is very sensitive.)
mildly implausible	Het oog bestaande uit onder andere een pupil, iris en wenkbrauw is erg gevoelig.
	(The eye consisting of among other things a pupil, iris and eyebrow is very sensitive.)
deeply implausible	Het oog bestaande uit onder andere een pupil, iris en *sticker* is erg gevoelig.
	(The eye consisting of among other things a pupil, iris and sticker is very sensitive.)
Syntactic agreement	
syntactic correct	De schone kleren en handdoeken hangen aan de waslijn te drogen.
	(The clean clothes and towels hang out on the clothesline to dry.)
syntactic incorrect	De schone kleren en handdoeken hangt aan de waslijn te drogen.
	(The clean clothes and towels hangs out on the clothesline to dry.)

Note: The critical word is underlined and the translation is given in parentheses.

In addition, to obtain a more objective measurement of the plausibility of the critical materials a latent semantic analysis (LSA, see http://lsa.colorado.edu/) was conducted on an English translation of the experimental sentences (see Van de Meerendonk et al., 2010 for the procedure). Twelve trials were excluded from the LSA analysis because no translation could be found for a portion of the nouns. The mean semantic similarity value (SSV) for the 150 trials was 0.36 for the plausible, 0.28 for the mildly implausible, and 0.18 for the deeply implausible sentences. An ANOVA indicated that these differences in mean SSV were reliable across the three conditions ($p<.001$), and this was also reflected in the follow-up pairwise comparisons between the SSV values of the three plausibility conditions (all ps<.001). The LSA analysis thus confirmed that the three conditions differed in semantic plausibility.

The three conditions of a sentence only differed in the critical words used. The critical words could be maximally three syllables long and across the three conditions did not differ in mean length (p>.1). Furthermore, for each critical word the frequency was searched using the CELEX lemma database (Baayen, Piepenbrock, & Gulikers, 1995). Mean frequency did not differ across conditions (p>.1). The sentences had a mean length of eleven words and the position of the critical word varied across the sentences.

The 162 experimental contexts were split in half to ensure that a participant would see different contexts in the fMRI study and the EEG study in which they also participated (for the EEG results, see Van de Meerendonk, Chwilla, & Kolk, submitted). For each half, three experimental lists were created such that the three sentence versions of each context were counterbalanced across lists and participants saw only one version of a sentence. Therefore, each list consisted of 27 plausible, 27 mildly implausible, and 27 deeply implausible sentences. Furthermore, 42 out of 84 fillers were added to each list. Of these 84 fillers, 56 sentences did not contain any violation. The remaining 28 sentences contained a semantic violation and were adapted from Vissers et al. (2006). In addition, 20 null events were added per list. They consisted of a fixation cross followed by a blank screen for the remainder of the trial. The trials were pseudorandomized using the following constraints: each list began with two filler trials, filler or experimental trials never occurred more than three times in a row, and violations and a certain condition never occurred more than three times in a row.

Sentence conditions – syntactic materials

In total, 108 sentence contexts were created. Each sentence context had two sentence versions: a syntactically correct and a syntactically incorrect version that contained an agreement violation on the verb (see Table 1 for an example, and Appendix 3 of this thesis). Half of the sentences contained a critical verb that was singular and half a critical plural verb. Furthermore, half of the subject NPs had animate and half had inanimate referents. The mean length of the sentence and the mean length and mean position of the critical word were matched to the plausibility experimental trials.

The 108 experimental contexts were split in half, resulting in 54 experimental sentences per list. Four experimental lists were created such that the two sentence versions of each context were counterbalanced across lists and participants saw only one version of a sentence context. Therefore, each list consisted of 27 syntactically correct and 27 syntactically incorrect sentences. In addition, 20 null events were added per list. The trials were pseudorandomized in such a way that a certain condition never occurred more than three times in a row, and syntactically correct and incorrect trials were equally often preceded by a syntactically correct or incorrect trial.

Sentence conditions – visual degradation materials

As for the syntactic materials, 108 sentence contexts were created. These contexts were adapted sentences from the low cloze probability correct condition of Van de Meerendonk et al. (2011). These were sentences that were weakly predictive of a critical word (e.g., 'They do not want the <u>customers</u> to see the mess.'). Each sentence context could be presented in two ways: the critical word could be visually degraded or not. Visual degradation was accomplished by randomly removing 75% of the pixels from the critical word. A pre-test in which 4 participants read the sentences out loud was conducted to ensure that although degradation made the words more difficult to read, the accuracy was high (mean error percentage 2%). The mean frequency, mean length of the sentence and the mean length and mean position of the critical word were matched to the plausibility experimental trials.

To check whether the degradation procedure was effective in raising the difficulty of reading the critical words, a pilot study consisting of a self paced reading task with 14 participants (12 women; mean age = 20.1 years; age range = 18 to 25 years) was conducted. Each participant saw half of the materials, such that no sentence context was repeated. The results showed that the reading times of the critical words were significantly slower for the visually degraded (926 msec) compared to undegraded condition (564 msec) [$F(1,13)=99.1$, $p<.001$].

The 108 experimental contexts were split in half, resulting in 54 experimental sentences per list. Four experimental lists were created such that the presentation versions of each context were counterbalanced across lists and participants saw only one version of a sentence. Therefore, each list consisted of 27 undegraded and 27 degraded trials. In addition, 20 null events were added per list. The trials were pseudorandomized using the same constraints as for the syntactic materials. Undegraded and degraded trials were equally often preceded by an undegraded or degraded trial.

Sentence conditions procedure

The stimuli were presented visually using the Presentation software (Neurobehavioral Systems, www.neurobs.com). Participants were tested individually lying in the scanner, viewing the stimuli via a mirror attached to the head coil.

The sentences were presented in white capitals at the center of the screen on a grey background in serial visual presentation mode. The words had a duration of 350 msec and a stimulus onset asynchrony of 645 msec. The length of the inter-trial interval, during which a fixation cross was shown, was jittered between 3300 and 5700 msec (mean 4500 msec), followed by a 500 msec blank screen.

To ensure that the participants attentively read the sentences, 10 percent of the sentences was followed by a comprehension question (‘yes/no’) about the previous sentence. The participants had to respond by pressing a button with the left index or left middle finger. Left-hand responses were used, instead of responses with the right-hand, to avoid left hemispheric motor activation. When the participants pressed a button or failed to respond within 3 sec, the question disappeared from the screen. Questions to which the participants failed to respond within 3 sec were counted as an error.

The presentation of the sentence conditions was divided into 4 runs (2 plausibility, 1 syntactic and 1 visual degradation block) with pauses in between. The order of the blocks was counterbalanced across subjects with the provision that the two plausibility blocks always followed each other. This ‘blocked design’, in which the various anomalies were not mixed, was chosen for comparability to our previous studies and because list composition has been found to influence results (e.g., Chwilla et al., 2000). Following these 4 sentence runs, the participants completed the Stroop task in a separate run. This made a total of 5 runs, which each lasted about 15 minutes.

Stroop task materials and procedure

The stimuli for the Stroop task were based on those of Milham et al. (2001). Participants were instructed to indicate the ink color in which a word was written by pressing a button. Three buttons were used, corresponding to the three ink colors that were possible: green, blue and yellow. To avoid left-hemispheric motor activation, each of the three colors was mapped to one finger of the left hand except the thumb and little finger. The task consisted of two factors: response type (eligible, ineligible) and trial type (incongruent, neutral). This resulted in four conditions: incongruent eligible, neutral eligible, incongruent ineligible, and neutral ineligible. For incongruent eligible trials the written word denoted a color that was a potential response (i.e., GROEN (green), BLAUW (blue) and GEEL (yellow)). For incongruent ineligible trials the written word denoted a color that was not a possible response (i.e., BRUIN (brown), ORANJE (orange) and ROOD (red)). The neutral eligible trials consisted of words that were matched in length and frequency to the words used in the incongruent eligible trials (i.e., DRANK (beverage), KRING (circle) and STOK (stick)). The neutral ineligible trials consisted of words that were matched in length and frequency to the words used in the incongruent ineligible trials (i.e., TROUW (fidelity), DALING (reduction) and HUID (skin)).

The task consisted of two eligible blocks and two ineligible blocks. The blocks were alternated (eligible-ineligible-eligible-ineligible) and separated from each other by a 10 sec break. All blocks contained 36 experimental trials, half of which were incongruent and half of which were neutral trials. The order of the trials within a block was pseudorandomized such that incongruent and neutral trials were equally often preceded by an incongruent or neutral trial. In addition, per block 9 null events were interspersed in the experimental trials.

A procedure similar to the one of Derrfuss et al. (2004) was used. Each trial started with a variable jitter interval (0, 500, 1000, 1500 msec), followed by a fixation cross (200 msec) and a blank screen (300 msec). Then the stimulus was presented (1500 msec) followed by a blank screen for the remainder of the trial (all trials lasted 4,78 sec). The target disappeared as soon as a response was given, and the maximum response time was 2 sec.

Data acquisition and analysis

The fMRI data were acquired on a 3T Siemens Trio scanner. The functional images were obtained using a parallel-acquired multi-echo EPI, in which images were acquired at multiple TE's following a single excitation (TE1 at 9.4 msec, TE2 at 21.2 msec, TE3 at 33 msec, TE4 at 45 msec, TE5 at 56 msec). Using such a multi-echo sequence increases BOLD contrast sensitivity by improving the estimate of T2* – which varies across the brain – because it mixes into the echoes differently. In addition, using a short parallel-accelerated EPI readout for the echoes reduces image distortion (e.g., Poser & Norris, 2009; Poser, Versluis, Hoogduin, & Norris, 2006). The TR was 2390 msec and each volume consisted of 31 slices with a voxel size of 3.5x3.5x3.0 mm. The anatomical images were obtained using a T1-weighted MP-RAGE GRAPPA sequence (TR = 2300 msec, TE=3.03 msec, 192 slices, voxel size = 1.0x1.0x1.0 mm).

The fMRI data were preprocessed and analysed using the SPM8 software (http://www.fil.ion.ucl.ac.uk/spm). The first five volumes of each run were discarded to allow for T1 equilibration effects. Then the five echoes of the remaining images were realigned to correct for motion artefacts and they were combined into one image. The resulting images were slice-time corrected and each subject's mean functional image across all echoes was coregistered to the subjects' anatomical T1 image. Subsequently, the images were anatomically normalized to a T1 template image and smoothed with an 8 mm FWHM Gaussian kernel.

The data of the plausibility, syntactic, visual degradation and Stroop materials were analysed separately. At the first level, single-subjects analyses were conducted. The linear models of each subject for the sentence materials included regressors that modelled the experimental conditions (i.e., plausible, mildly implausible and deeply implausible; syntactically correct and incorrect; visually undegraded and visually degraded) from the critical word onwards to the end of the sentence. The correct experimental sentence beginnings (until the word before the critical word) were included in a 'general correct' regressor. Furthermore, regressors were included for the inter-trial interval in which a fixation was shown, for the null events (NULL), and for six realignment parameters describing head movements. In addition, for the plausibility materials two regressors were added for the correct and incorrect fillers. The linear models of each subject for the Stroop task included regressors that modelled the experimental conditions (i.e., incongruent eligible, neutral eligible, incongruent ineligible and neutral ineligible). In addition, a separate regressor was added for errors and for null events (NULL). The regressors were convolved with a canonical hemodynamic response function. For the second-level analysis, the contrast images from the first level were entered into a random effects group analysis.

Whole brain analysis

In the exploratory whole brain analysis we obtained the single-subject contrast images for all experimental conditions relative to NULL as a baseline. Differential effects of the experimental conditions were calculated at the second-level with a full factorial design for all material types. The results of the analyses were thresholded at $p<.001$ (uncorrected voxel level); only activation clusters at a threshold of $p<.05$ corrected at the cluster level are reported. All local maxima are reported as MNI coordinates.

Region of interest analyses

Individual Stroop ROI

An individual Stroop region of interest (ROI) was defined for each subject separately based on the Stroop materials. The individual Stroop ROI included those voxels in the lIFG which passed a threshold of $t=1.7$ ($p<.05$) for the contrast incongruent minus neutral, with the anatomical constraint that they should either fall in pars opercularis or pars triangularis (BA 44/45) (see January et al., 2009; Tzourio-Mazoyer et al., 2002). In line with January et al. (2009) we did not include voxels from the pars orbitalis (BA 47), since other types of cognitive control have been attributed to this region (see e.g., Badre & Wagner, 2007). One subject had to be excluded from the subsequent ROI analysis because no significant voxels remained for the individual Stroop ROI.

This ROI was tested in separate repeated measurement ANOVAs for the plausibility, syntactic and visually degraded materials. The ANOVAs were based on the contrast values that were obtained in the ROI from the single-subject contrast images for the experimental conditions versus NULL as a baseline using the Marsbar toolbox for SPM (Brett et al., 2002, http://marsbar.sourceforge.net).

Implausibility regions

An additional ROI analysis was conducted on the plausibility conditions to investigate whether increasing implausibility affected the hemodynamic response. A previous EEG study by Van de Meerendonk et al. (2010) found that the mildly implausible condition elicited a different ERP pattern (N400 effect), than the deeply implausible condition (biphasic N400-P600 effect). In accordance with the monitoring theory of language perception (for a review see Van de Meerendonk et al., 2009) this result was explained in terms of differences in conflict strength: only when the mismatch between an expected and observed linguistic element is strong enough reprocessing is triggered, eliciting a P600. In the case of mildly implausible sentences (e.g., *eyebrow* as part of the eye, see Table 1), the mismatch between the expected and actually observed element is supposed to be weaker, since the observed element is closer to the expectation (as reflected by the plausibility ratings and LSA analysis). Therefore, participants try to integrate the information into the context because they want to make sense of what they read, and a monophasic N400 effect is elicited. However, in the case of deeply implausible sentences (e.g., *sticker* as part of the eye, see Table 1) integration fails, since the observed element is not in line with the expectation at all (cf., plausibility ratings and LSA analysis), thereby creating a stronger mismatch and eliciting reprocessing (hence a biphasic N400-P600 pattern). Therefore, we hypothesized that any brain area that is sensitive to this conflict strength manipulation should differentiate between the mildly and deeply implausible condition as well. A previous fMRI study that investigated spelling errors and manipulated conflict strength (i.e., the mismatch between an expected and observed element) by using high- and low-cloze sentences, did not report any modulation in the hemodynamic response (Van de Meerendonk et al., 2011). This null finding, however, does not preclude that the hemodynamic response can be affected by manipulations of conflict strength, and therefore we investigated this in an additional ROI analysis on the plausibility conditions.

The ROIs in this analysis were based on significantly activated clusters in a T-test of the contrast comparing both implausible conditions (mildly and deeply implausible) to the plausible condition. These ‘implausibility regions’ included lIFG (BA 44/45), right inferior frontal gyrus (rIFG), left middle frontal gyrus (lMFG), left cerebellum, right middle temporal gyrus (rMTG), right superior temporal gyrus (rSTG) and left pre/postcentral gyrus (see Table 2). A 2 x 7 repeated measurement ANOVA was conducted, including the factor plausibility (mildly implausible, deeply implausible) and ROI (lIFG, rIFG, lMFG, left cerebellum, rMTG, rSTG, and left pre/postcentral gyrus). Again, the ANOVA was based on the contrast values that were obtained in the ROIs from the single-subject contrast images for the plausibility conditions versus NULL as a baseline using the Marsbar toolbox for SPM (Brett et al., 2002, http://marsbar.sourceforge.net).

Table 2. Implausibility ROIs based on significant activated clusters for the contrast comparing both implausible conditions (mildly and deeply implausible) to the plausible condition.

Region	BA	Cluster size	Voxel T value	x	y	z
Right inferior frontal gyrus	45	2344	6.58	50	26	12
			6.45	40	36	4
			5.83	44	18	22
Left inferior frontal gyrus	44/45	1285	6.10	-48	26	8
			5.63	-42	32	10
			5.43	-48	38	8
Right middle temporal gyrus	20/21	1027	5.78	40	-24	-10
			4.91	44	0	-22
			4.72	42	-40	6
Left cerebellum		264	6.93	-46	-54	-28
			4.17	-36	-52	-26
Left middle frontal gyrus	10	223	4.84	-26	44	22
			4.32	-34	44	24
			4.05	-28	50	30
Left pre/postcentral gyrus	4/6	197	6.28	-22	-28	52
			5.33	-16	-22	60
			4.56	-18	-44	58
Right superior temporal gyrus	13/22	192	5.09	40	-44	28
			4.95	36	-44	20
			3.97	34	-50	14

Note: Table shows all clusters at a significance level of $p<.05$ corrected at the cluster level (thresholded at $p<.001$ uncorrected). All local maxima are reported as MNI coordinates.

Results

Behavioral results

Sentence comprehension task

Mean error rate on the comprehension questions was 8.9 % (plausibility materials: 6.9%; syntactic materials: 8.3%; visual degradation materials: 13.2%). One participant was excluded from both the behavioural and fMRI analyses because more than 6 errors (25%) were made in total. The low error percentages indicate that the participants read the sentences attentively.

Stroop task

For the Stroop task, 95% or more of the trials were responded to correctly by the participants (mean percentage of correct trials 98%). Response times (excluding errors) that were more than 3 SD above a subject's grand mean were trimmed to the cutoff value. This affected 1.53% of the data. A repeated-measures ANOVA with the factors response type (eligible, ineligible) and trial type (incongruent, neutral) yielded a main effect of trial type [$F(1,23) = 30.59$, $p<.001$], with no effect of response type [$F(1,23) = 0.82$, $p>.1$]. There was no significant interaction between response type and trial type [$F(1,23) = 0.54$, $p>.1$], indicating the same interference effect for eligible and ineligible trials (mean RT eligible incongruent = 623 msec; eligible neutral = 583 msec; ineligible incongruent = 609 msec; ineligible neutral = 577 msec).

fMRI results

Whole brain analysis

A list of significant activations can be seen in Table 3. In the whole brain analysis of the plausibility data the contrast mildly implausible > plausible yielded significant results in rIFG (BA 45), lIFG (BA 45/47), right precentral gyrus, left postcentral gyrus, and right cerebellum. The contrast deeply implausible > plausible resulted in significant activations in the rIFG (BA 45/47) and right middle temporal gyrus. Comparing the mildly and deeply implausible conditions only yielded significant effects for the contrast mildly implausible > deeply implausible. The right pre- and postcentral gyrus were activated more strongly for the mildly compared to the deeply implausible condition (see Table 3a). For the syntactic data, the contrast syntactically incorrect > syntactically correct indicated a significant cluster in the rIFG (BA 45/47) (see Table 3b). In the whole brain analysis of the visual degradation data a comparison was made between the visually degraded and the undegraded conditions. Regions that were significantly stronger activated for the visually degraded versus the undegraded condition included the right and left inferior temporal/fusiform gyrus (see Table 3c).

The Stroop data showed a significant cluster in lIFG (BA 44/45) for the contrast incongruent > neutral (collapsing over eligible and ineligible trials). When comparing only the data of the eligible incongruent with eligible neutral trials, more activation was found for the incongruent condition in lIFG (BA 44/45), left inferior parietal/angular gyrus and left middle temporal gyrus (see Table 3d). No significant results were obtained for the ineligible incongruent > ineligible neutral contrast.

Region of interest analyses

Individual Stroop ROI

Figure 1 depicts the mean contrast values for all experimental conditions in the individual Stroop ROI. The results indicated a main effect across the three levels of plausibility [$F(2,21)=5.40$, $p<.05$]. Comparing the three levels pairwise showed that both mildly implausible [$F(1,22)=11.26$, $p<.01$] and deeply implausible [$F(1,22)=4.56$, $p<.05$] elicited increased activation in the ROI compared to the plausible condition. Comparing the mildly and deeply implausible condition showed significantly stronger activation for the mildly than the deeply implausible condition [$F(1,22)=6.25$, $p<.05$]. In addition, there was a main effect for the syntactic materials [$F(1,22)=6.12$, $p<0.05$], indicating stronger activation for the syntactically incorrect condition than the syntactically correct condition. The visual degradation materials also yielded a main effect in the individual Stroop ROI [$F(1,22)=6.19$, $p<.05$]. More activation was elicited in the visually degraded condition than the undegraded condition.

Table 3. Significant clusters at the whole brain level.

Region	BA	Cluster size	Voxel T value	x	y	z
a. mildly implausible > plausible						
Right inferior frontal gyrus	45	2165	5.02	18	4	18
			4.87	38	20	22
			4.66	36	36	8
Left inferior frontal gyrus	45/47	1758	4.98	-40	40	-2
			4.98	-40	40	-14
			4.76	-52	32	10
Right pre/postcentral gyrus	3/4/6	823	4.52	42	-8	40
			4.24	52	-4	44
			3.82	54	-8	22
Left pre/postcentral gyrus	4/6	295	4.49	-28	-8	40
			3.77	-46	-12	44
			3.68	-36	-10	44
Right cerebellum		293	3.78	12	-44	-38
			3.65	20	-40	-36
deeply implausible > plausible						
Right inferior frontal gyrus	45/47	735	4.72	38	20	20
			4.55	50	30	10
			4.11	32	28	-12
Right middle temporal gyrus	20/21	725	5.02	50	0	-22
			4.93	42	-2	-22
			4.8	50	8	-30
mildly implausible > deeply implausible						
Right pre- and postcentral gyrus	3/6	384	3.90	46	-22	46
			3.76	54	-6	48
			3.70	38	-8	40
b. syntactically incorrect > syntactically correct						
Right inferior frontal gyrus	45/47	337	4.71	46	42	-8
				44	32	-6
c. visually degraded > undegraded						
Right inferior temporal/fusiform gyrus	20/37	1718	6.79	32	-42	-22
			6.22	32	-50	-18
			5.45	42	-64	-10
Left inferior temporal/fusiform gyrus	37	1253	6.61	-38	-52	-16
			6.46	-32	-46	-20

Region	BA	Cluster size	Voxel T value	x	y	z
d. Stroop incongruent > neutral						
Left inferior frontal gyrus	44/45	776	5.36	-46	22	22
Stroop eligible incongruent > eligible neutral						
Left inferior frontal gyrus	44/45	1498	5.49	-48	22	20
			4.20	-38	2	32
			3.97	-46	22	34
Left inferior parietal/angular gyrus	39/40	341	3.85	-50	-50	42
			3.77	-48	-62	26
			3.63	-54	-56	32
Left middle temporal gyrus	21	284	4.81	-54	-32	-6
			3.66	-52	-44	-6

Note: The table shows all clusters at a significance level of $p<.05$ corrected at the cluster level (thresholded at $p<.001$ uncorrected). All local maxima are reported as MNI coordinates.

Implausibility regions

The 2 x 7 repeated measurement ANOVA yielded an interaction of Plausibility x ROI [$F(6,18)=2.73$, $p<.05$]. Follow-up analyses per ROI indicated that none of the ROIs showed significant differences when comparing the mildly and deeply implausible condition (all ps.>.2). Only in the lIFG there was a trend for a stronger activation for the mildly compared to the deeply implausible sentences [$F(1,23)=3.49$, $p=0.075$] (mean contrast value mildly implausible=1.56, deeply implausible=1.24).

Discussion

The aim of the present study was twofold. First, we further investigated the proposal of a general conflict resolution mechanism in lIFG (e.g., Novick et al., 2005) in relation to errors in language perception. To this end, an fMRI experiment was conducted that investigated within the same group of participants representational conflicts created by syntactic and plausibility violations, using the conflict created by a Stroop task as a localizer for cognitive control processes. Second, we studied whether conflicting representations are required for lIFG engagement, or whether other cognitively demanding inputs can signal the need for adjustments in control as well. Therefore, a visual degradation condition was added for which no conflict between multiple

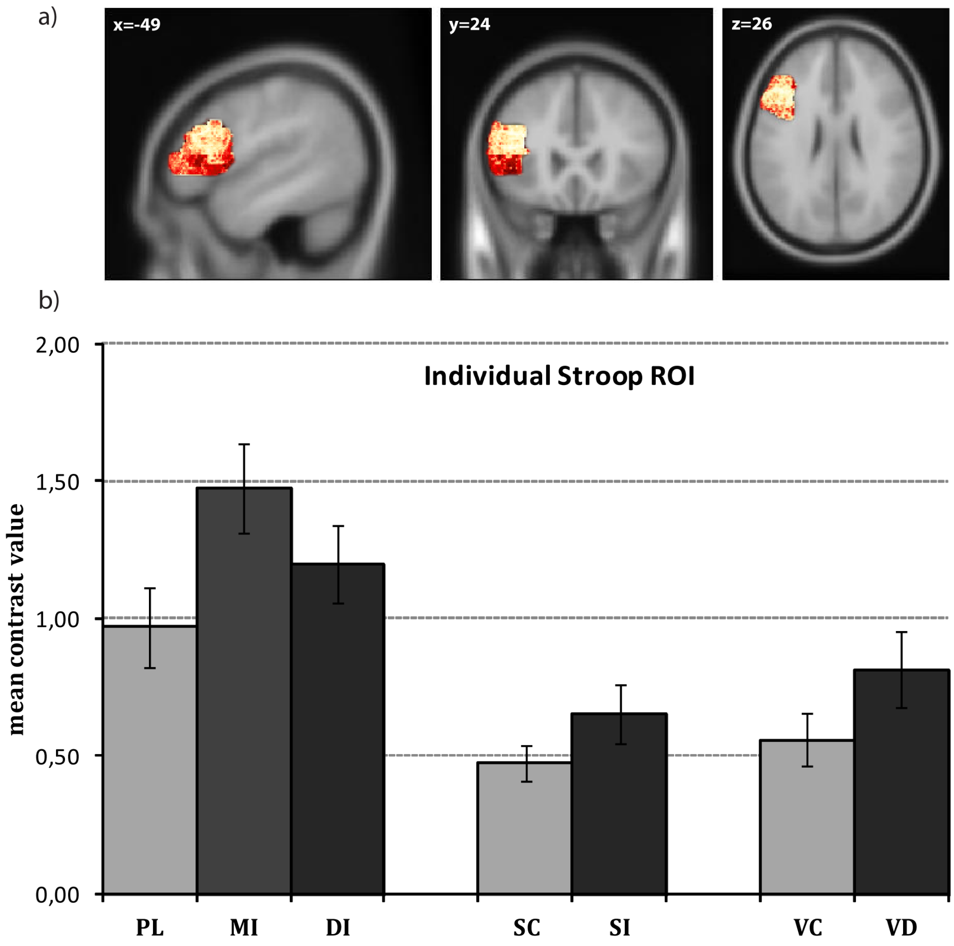

Figure 1. a) The brain maps on top show the overlap of the individual Stroop ROIs across subjects; the brighter yellow the color the more overlap, the more red colors indicate less overlap. b) The figure below shows the mean contrast values in the individual Stroop ROI for the plausibility materials (plausible (PL), mildly implausible (MI), deeply implausible (DI)), syntactic materials (syntactically correct (SC), syntactically incorrect (SI)), and the visual degradation materials (visually correct (VC, i.e., undegraded), visually degraded (VD)). Error bars indicate standard error of the mean.

representations was assumed to be present. However, what connects the degradation condition with the various conflict conditions is the need for compensatory control adjustments to identify the correct word, which could involve the lIFG.

The results from the ROI analyses indicated co-localized activation in the lIFG for both syntactic and plausibility violations with the Stroop interference effect. These results contribute to the findings by January et al. (2009) by showing that next to syntactic ambiguity, syntactic agreement violations and plausibility violations elicit co-localized activation with the Stroop conflict in the lIFG as well. Hence, this further extends the proposal of a general conflict resolution mechanism in lIFG to representational conflicts arising from errors in language perception. In addition, these results indicate that next to spelling errors (see Van de Meerendonk et al., 2011), violations of plausibility also elicit co-localized activation with syntactic violations in the lIFG. Therefore, at least with respect to representational conflict resolution, these findings do not support the proposal that different language processes (i.e., syntactic, semantic, and phonological processes) are subserved by different subregions within lIFG (e.g., Bookheimer, 2002). Instead, the findings of co-localized activation for different types of conflict further strengthen the proposal that cognitive control mechanisms in the lIFG are recruited to resolve various types of conflict (e.g., Novick et al., 2005; Thompson-Schill et al., 2005; Thompson-Schill et al., 1997).

In addition, the ROI analyses in the present study indicated co-localized lIFG activation of the various conflict conditions with the visual degradation condition, for which no conflict between an expected and observed representation was assumed to be present. As was the case for the other experimental conditions, the visually degraded words elicited more lIFG activation than their undegraded counterparts. Since for the visual degradation condition no representation can be formed based on expectations and the critical word does not contain an error of any kind, this finding could indicate that a conflict between competing representations is not necessary to elicit lIFG involvement to bias attention. However, just as in the case of representational conflicts, the visual degradation condition could call for the need for compensatory adjustments in control to bias attention towards the relevant information. In the case of competing representations, attention has to be biased towards the unexpected or non-prepotent representation to resolve the conflict. In the case of degraded stimuli, biasing of attention is needed to compensate for the lack of bottom-up information to identify the word.

The proposal that the lIFG is engaged more generally when a biasing of attention is needed is in line with the findings in the review by Duncan and Owen (2000). In their meta-analysis they included studies that investigated diverse tasks that entailed varying degrees of cognitive demand. These tasks for example examined response conflict (high vs. low conflict), the retention of a number of elements in working memory (higher vs. lower load), working memory delay (long vs. short delay), task novelty (early vs. late learning), and perceptual difficulty (more vs. less perceptually demanding). The meta-analysis indicated that a specific network in prefrontal cortex, including the lIFG, was recruited by increases in demands to solve these different types of cognitive problems. We propose that the way these diverse problems are solved is by making control adjustments in the allocation of attention. As is the case for the conflict stimuli and the degraded stimuli used in the present experiment, all the tasks reviewed by Duncan and Owen (2000) could be said to require adjustments in the allocation of attention; due to the increase in cognitive demand a biasing of attention is needed, a process which Kahneman (1973) refers to as mental effort.

Note, however, that in the literature two types of representational conflict have been distinguished, and for both types involvement of the lIFG has been indicated. The first type of conflict, which we have discussed throughout this article, requires that a prepotent response or representation is overridden (e.g., Stroop task, garden-path sentences, and strong expectancy violations). The second type of conflict is the so called 'underdetermined response conflict', in which competition between multiple weakly activated representations is present. An example of a task that gives rise to this second type of conflict is the category fluency task. In this task participants for instance have to name as many exemplars of the category 'fruits'. Since all exemplars within this category are equally valid, they elicit underdetermined response conflict (see e.g., Botvinick et al., 2001; Novick, Kan, Trueswell, & Thompson-Schill, 2009; Thompson-Schill et al., 2005). It is possible that the visual degradation condition in the present study creates a similar kind of underdetermined response conflict, because degraded words may give rise to several weakly activated representations since the words are difficult to read. Therefore, one could argue that what underlies the lIFG activation in the degraded condition is again representational conflict resolution. If such a conflict is present in the degraded condition, however, it would differ from the representational conflicts elicited by the syntactic agreement violations and the plausibility violations, where there is a conflict between *two* incompatible representations: one stemming from an expected linguistic element and the other stemming from an encountered violation. This difference has important consequences for the type of adjustment of control one could expect. In the case of syntactic agreement violations and plausibility violations – as well as in the case of the Stroop task and ambiguous sentences – control could involve the strengthening of the non-automatic (i.e., the unexpected or non-prepotent) representation. However, it is entirely unclear which of the multiple word representations, elicited in the degradation condition, should be strengthened since all representations are equally 'expected', 'automatic' or 'prepotent'. Although at this point, we are unable to indicate what type of control would be needed to compensate for the temporary lack of bottom-up information, it is unlikely that it would be the same type of selective attentional strengthening, needed to resolve representational conflicts, that occurs in the Stroop task, ambiguous sentences and after syntactic and semantic anomalies.

An additional finding in the present study was that the ROI analysis of the implausibility regions yielded a trend for a stronger lIFG activation for the mildly compared to the deeply implausible condition. Furthermore, this effect was significant in the lIFG region defined by the individual Stroop ROI. As indicated in the methods section, a previous EEG study by Van de Meerendonk et al. (2010) yielded a different ERP pattern for the mildly (N400) and deeply implausible condition (N400-P600). Based on the monitoring theory of language perception (for a review see Van de Meerendonk et al., 2009) this result was explained in terms of differences in conflict strength – that is, the strength of the mismatch between the expected and observed implausible element. In the case of the mildly implausible condition (e.g., *eyebrow* as part of the eye, see Table 1) the observed implausibility is semantically closer to the expectation, and therefore the mismatch is supposed to be weaker. Participants may try to extend the concept (e.g., of the eye) to integrate the unexpected meaning in the sentence, eliciting an N400 effect. For the deeply implausible condition (e.g., *sticker* as part of the eye, see Table 1), however, there is a stronger mismatch between the expected and observed element, since the critical word is farther removed from the expectation. In this case, integration fails and reprocessing is triggered, eliciting a P600 effect. The finding of stronger lIFG activation for the mildly compared to the deeply implausible condition, could suggest that these different ways of dealing with mildly and deeply implausible sentences, might require different control adjustments. For the deeply implausible condition, it may be almost immediately clear that the encountered implausibility does not fit within the sentence and should not be integrated. Therefore, control adjustments are needed to override the prepotent response (i.e., the expected representation) and attention is biased towards the unexpected representation to check whether an error occurred. For the mildly implausible condition, the expected representation is less prepotent relative to the observed one, and control adjustments might be needed to actually integrate the unexpected meaning. It is possible that the unexpected information in the mildly implausible sentences has to be maintained longer for this integration to succeed, thereby requiring more or longer attentional enhancement eliciting stronger lIFG activation. This seems to suggest that participants have more difficulty in dealing with the mildly implausible than the deeply implausible condition. In line with this suggestion, a separate behavioral pilot study of our plausibility materials indicated that participants were significantly slower ($p<.001$) to judge plausibility for the mildly implausible sentences (821 msec) compared to the deeply implausible sentences (455 msec).[15]

In sum, the results of the present study further strengthen and possibly extend the proposal of a general conflict resolution mechanism in the lIFG (e.g., Novick et al., 2005; Thompson-Schill et al., 2005; Thompson-Schill et al., 1997). The finding of co-localized lIFG activation for representational conflicts arising from various types of language errors with representational conflict in the Stroop task, further strengthens the conflict resolution account of the lIFG and connects it to language perception errors. Furthermore, the finding that the visual degradation condition shows co-localized lIFG activation as well, could indicate that the lIFG also plays a role in situations in which a biasing of attention is needed to compensate for a lack of bottom-up information. Therefore, the lIFG might be engaged in compensatory adjustments in control to resolve situations in which extra attention is needed more generally. In the case of the Stroop task, ambiguous sentences, and errors in language perception a biasing of attention is needed to override the prepotent or expected representation. For the Stroop task and the ambiguous sentences this means that the task relevant information (i.e., the ink color) or the relevant parse become selected. For errors in language perception the biasing of attention towards the unexpected representation could lead to a reprocessing

[15] In the behavioral pilot of the plausibility materials 24 participants conducted a judgment task (18 women; mean age=20.3 years; age range=18 to 25 years). The materials were split in three lists such that the three sentence conditions were counterbalanced across lists and each participant saw each sentence context only once. Sentence presentation was similar to the fMRI experiment, but only up till the last word of the summation. After each sentence participants made a judgment by pressing one of two buttons (plausible: yes/no) with the right or left index finger randomly assigned per subject.

of the input to check for possible errors, or it could involve the maintenance of information for integration processes. Furthermore, in the case of visually degraded words, a biasing of attention is needed to compensate for a lack of bottom-up information.

The proposal that the lIFG is engaged to resolve situations in which extra attention is needed more generally is inconsistent with some proposals from the language comprehension literature. As discussed in the introduction, some of these proposals view Broca's area as primarily dealing with syntactic processing as such (e.g., Bahlmann et al., 2008; Friederici et al., 2009; Grodzinsky, 2000; Grodzinsky & Santi, 2008) or as specifically involved in syntactic working memory (Fiebach et al., 2005). However, instead of reflecting syntax specific linguistic processing the activation within lIFG in the present study appears to reflect the control of linguistic processing more general. A connection to this proposal might be the account by Hagoort (2005) that the lIFG plays an important role in the maintenance of syntactic, semantic and phonological information, in order for these informational types to become integrated with one another – a process referred to as unification. This could relate to the present finding that the mildly implausible condition, which might require longer maintenance, activate the lIFG more strongly. However, according to Hagoort (2005), attentional control as is needed in case of the Stroop task, should not activate the lIFG but the dorsolateral prefrontal cortex (BA 46, 9) (and the anterior cingulate cortex). This is clearly at variance with our finding that the Stroop task, as well as different types of language errors and the visual degradation condition, all activate the lIFG.

Further evidence for the proposal that the lIFG is involved in the control of linguistic processing more general, and not in syntactic processing as such, comes from patient studies (e.g., Novick et al., 2009; Robinson, Blair, & Cipolotti, 1998; Thompson-Schill et al., 2002). For instance, Novick et al. (2009) studied a patient (I.G) with a focal lesion to the lIFG. Compared to healthy subjects and a frontal control group with no lesions in lIFG, I.G. performed significantly worse on tasks which created conflicts between multiple representations. This difficulty was not restricted to syntactic tasks: the patient showed a general conflict resolution impairment for language comprehension and production when syntactic, semantic and/or conceptual representations competed. Therefore, Novick et al. (2009) conclude that the language impairments that arise from lesions to the lIFG are not specific to the linguistic processes as such, but they arise from a more general failure of cognitive control. Regarding the present study this could indicate that, compared to controls, patients with focal lesions to lIFG may also show differences in processing errors in language perception and in dealing with visually degraded stimuli. For instance, degraded stimuli might lead to increased reading times in patients compared to controls. However, future studies are needed to investigate the specific (comprehension) consequences of errors in language perception and of degraded words for patients with focal lIFG lesions.

To conclude, the results of the present study contribute to the unifying account of lIFG functioning in the cognitive control literature and the psycholinguistic literature (e.g., Novick et al., 2005). This indicates that language perception is more in need of attentional control than is often assumed. In particular, the outcome of the present study suggests that adjustments in attentional control are needed to check for perceptual errors, to integrate deviant information, and to compensate for a temporary lack of bottom-up information.

Chapter 6

States of indecision in the brain: ERP reflections of representational conflicts versus visual degradation

This chapter is currently under revision:

Van de Meerendonk, N., Chwilla, D.J., & Kolk, H.H.J. (under revision). States of indecision in the brain: ERP reflections of representational conflicts versus visual degradation.

Abstract

According to the monitoring theory of language perception, strong conflicts between expected and observed linguistic elements signal the need for adjustments in control. When a strong conflict between competing representations is present, a biasing of attention towards the unexpected representation leads to reprocessing of the input to check for possible processing errors. This monitoring response has consistently been shown to elicit a P600 effect. The present ERP study compared two types of representational conflicts (i.e., syntactic agreement violations, and plausibility violations) with another cognitively demanding input that can also signal the need for adjustments in control, namely a lack of bottom-up information due to visual degradation. The results showed that both representational conflicts and a lack of bottom-up information elicited long-lasting positivities. It is proposed that a general monitoring process, which evaluates the demands for control, underlies these positivities. In the case of representational conflicts, adjustments in attentional control are needed to bias the unexpected representation. In the case of a lack of bottom-up information, extra attention is needed to identify the word. An unexpected finding was that the ERP pattern to syntactic agreement violations was influenced by the presentation order. Participants who had seen the syntactic block before the visual degradation block showed a standard P600 effect to agreement violations, while participants who had seen the visual degradation block first showed an N400 effect. This finding is taken to indicate that different strategies can develop to process agreement violations, depending on the context in which they are embedded.

Introduction

On a daily basis we process hundreds of sentences, either while listening to others or while reading a text. Most of the time, this comprehension process proceeds quite effortlessly, demanding little of our attention. However, this smooth comprehension process can be interrupted when problems arise, for example, when we mishear what someone is saying or misread a word in a text. For instance, take the following sentence: 'Time flies like an arrow, fruit flies like a banana'. It is very likely that, if you read this sentence for the first time, you misread the second *flies* as a verb, where actually it should be read as a noun. A process that deals with the detection and resolution of such problems is monitoring.

Monitoring is a term often used in the cognitive control literature and it refers to a process that evaluates the demands for control (e.g., McGuire et al., 1996; Stuss & Benson, 1986). In the recent past, we have investigated one of the problems in visual language comprehension that signals the need for adjustments in control: the presence of a strong conflict between what a text leads you to expect and the linguistic element that you actually observe. Such conflicts are called 'representational' because in this case we are dealing with two incompatible representations. We have studied the effect of these representational conflicts on event-related potential (ERP) components at various levels of linguistic description, in particular at syntactic, semantic and orthographic levels. Consistently, we have found that conflicts at all these levels elicited late positivities or P600 effects (Kolk et al., 2003; Van de Meerendonk et al., 2011; Van de Meerendonk et al., 2010; Van Herten et al., 2006; Van Herten et al., 2005; Vissers et al., 2006; Vissers et al., 2008). These findings, together with other studies that reported P600 effects to different kinds of semantic anomalies (e.g., Ganushchak & Schiller, 2010; Hoeks et al., 2004; Kim & Osterhout, 2005; Kuperberg et al., 2006; Kuperberg, Sitnikova, et al., 2003), challenge the view that the P600 reflects some form of syntactic processing (e.g., Friederici et al., 1996; Hagoort et al., 1993; Kaan et al., 2000; Osterhout & Holcomb, 1992). Therefore, to account for the P600 effects to various types of representational conflict, the monitoring theory of language perception was put forward (for reviews, see Kolk & Chwilla, 2007; Van de Meerendonk et al., 2009). According to the monitoring theory of language perception a strong conflict between an expected and observed linguistic element brings the language system into a state of indecision. It is like asking oneself: ‘Did I read that correctly?’. For example, we generally expect a grammatically correct inflection or a correctly spelled word, but when we encounter a wrong inflection or a spelling error this clashes with our expectation. In language perception, such a conflict could stem from two sources; the unexpected event indeed occurred, or a processing error was made. To clarify whether the initial reading was correct, attention is biased towards the unexpected event and reprocessing is triggered to check the input. This monitoring process is proposed to elicit the P600 effect in the EEG (but see e.g., Kim & Osterhout, 2005; Kuperberg, 2007 for different accounts on the P600 effects to semantic anomalies).

It is generally accepted that monitoring for the occurrence of conflicts between expected and observed outcomes could be one of the mechanisms to evaluate the demands for control. However, other cognitively demanding inputs might also signal that adjustments in control are needed (e.g., Botvinick et al., 2001). A good example of inputs that also disrupt visual language comprehension and thereby signal the need for control adjustments, are words that are difficult to read. This happens, for example, when we try to read a postcard from a person who has poor handwriting or when trying to decipher a text printed from a printer that has almost run out of ink. In these circumstances our understanding of the text is (temporarily) hampered and, as in the case of conflicting representations, this could bring the language system into a state of indecision (‘What does it say?’). The reason for this state of indecision, however, is different, as it is not brought about by a conflict between an expected and actually observed representation. Yet, although such a conflict does not occur, to identify the correct representation adjustments in control could also be necessary in that extra attention has to be allocated to facilitate the identification of the word(s) in the text.

This type of problem in language comprehension, arising from a lack of bottom-up information, has received little attention in language research so far. Therefore, the aim of the present study was to investigate whether the language user deals with this lack of bottom-up information in a similar manner as in the case of representational conflicts. To this end, the ERP response to a lack of bottom-up information was compared to the ERP response to representational conflicts in the same group of participants. In particular, the question was whether a lack of bottom-up information also leads to a monitoring response, and elicits a positivity in the P600 window, as in the case of a conflict between an expected and observed representation. For this reason, we created a visual degradation condition, which consisted of plausible sentences with no particular expectation for a certain word, in which the critical word could either be visually degraded or not. For the degraded critical words it is assumed that no conflict between an expected and observed representation occurs, since no representation can be formed based on expectations, and the critical word, though difficult to read, does not contain a violation of any kind. However, because the word is difficult to read, we assumed that it still disrupts comprehension and signals that adjustments in control are needed to identify the correct word.

The present EEG study is the first study, as far as we know, to investigate the influence of visual degradation of a word in a sentence on ERPs in language comprehension. Previous studies have investigated the effects of visual degradation on ERPs, but these studies used quite different paradigms and tasks. For example, in the language domain Holcomb (1993) used semantic priming to study the influence of visual degradation on the N400, which is generally thought to reflect semantic processing (e.g., Chwilla et al., 1998; Federmeier & Kutas, 1999; Kutas & Hillyard, 1980c, 1984). A prime and target word were shown and subjects had to make a lexical decision on the target word, which was semantically related or unrelated to the prime. Although the behavioural semantic priming effect (i.e., people are faster to respond to related than unrelated targets) was greater when the target was degraded, visual degradation of the target did not influence N400 amplitude, only its onset was somewhat delayed. In addition, other studies have investigated the effect of visual degradation of single letters or numbers in discrimination or mathematical tasks on ERP components (e.g., Chwilla & Brunia, 1991; Kok & Looren de Jong, 1980; Ruchkin, Johnson, Mahaffey, & Sutton, 1988). Kok and Looren de Jong (1980) found that visual degradation had an effect in the P300/N400 time window: visually degraded stimuli elicited a reduced P300 amplitude at parietal sites and a more negative N400 amplitude frontal-centrally. In contrast, Chwilla and Brunia (1991) found a more *positive* P300 amplitude for degraded stimuli which was maximal over frontal sites, while Ruchkin et al. (1988) reported no effect on P300 amplitude. Furthermore, all three studies reported late positivities for degraded stimuli: a parietal P500 and a central-parietal positive slow wave (700-800 msec) (Kok & Looren de Jong, 1980), a positive slow wave (800-1300 msec) at all but occipital sites (Chwilla &

Brunia, 1991), and a central-parietal positive slow wave (onset 500 msec, peak 1100 msec) (Ruchkin et al., 1988). Taken together, these studies indicate that there is an influence of visual degradation on various ERP components, but the nature and direction of this influence is not yet clear.

In the present study, to allow for a comparison of the brain response to the two different types of language comprehension problems, next to the visual degradation condition, two conditions were included for which a conflict between competing representations has been proposed to be present (see e.g., Van de Meerendonk et al., 2009). The first representational conflict condition contained standard syntactic agreement violations (e.g., "The clean clothes hangs…": see Table 1), which generally elicit increased P600 amplitudes compared to correct sentences (e.g., Hagoort et al., 1993; Osterhout & Mobley, 1995; Van de Meerendonk et al., 2011; Vos, Gunter, Kolk, & Mulder, 2001). The second representational conflict condition contained plausibility violations. This condition was added to also include a representational conflict that is not syntactic in nature, but which has also been shown to elicit P600 effects. Van de Meerendonk et al. (2010) previously studied these plausibility violations, and found that only representational conflicts that were sufficiently strong elicited a P600 effect. In particular, they compared both mildly implausible sentences (e.g., "…pupil, iris and eyebrow…") and deeply implausible sentences (e.g., "…pupil, iris and sticker…") to plausible ones (e.g., "…pupil, iris and retina…": see Table 1), and found that while mildly implausible sentences elicited a monophasic N400 effect, deeply implausible sentences elicited a biphasic N400-P600 pattern. These findings were interpreted as follows. In the mildly implausible condition it was still possible, though harder, to integrate the critical word in the sentence context, as reflected by the presence of an N400 effect. In contrast, integration was not successful in the deeply implausible condition. Therefore, only in the deeply implausible condition a check of the input was needed, which resulted in a P600 effect subsequent to the N400 effect.

To recapitulate, the general aim of the present study was to investigate whether the language user deals with a lack of bottom-up information in a similar way as with the presence of representational conflicts. To this end, within the same group of participants the ERP response to visually degraded words in a sentence was compared with the ERP response to two distinct types of representational conflicts (i.e., syntactic agreement violations, and plausibility violations). Based on the literature we predicted a standard P600 effect for syntactic agreement violations (e.g., Hagoort et al., 1993; Osterhout & Mobley, 1995; Van de Meerendonk et al., 2011; Vos et al., 2001), an N400 effect for mildly implausible sentences, and a biphasic N400-P600 pattern for deeply implausible sentences (Van de Meerendonk et al., 2010). We hypothesized that, if a lack of bottom-up information due to visual degradation is dealt with in a similar way as representational conflicts, then the visual degradation condition should also elicit a positivity in the P600 window. The late positivities that have been found in some degradation studies (e.g., Chwilla & Brunia, 1991; Kok & Looren de Jong, 1980; Ruchkin et al., 1988) could point towards a resemblance in the processing consequences of a lack of bottom-up information with the consequences of representational conflicts. However, if both types of problems in language comprehension are processed differently, then the visual degradation condition should not elicit a positivity in the P600 window.

Methods

Participants

Thirty healthy right-handed native speakers of Dutch participated in the experiment. Twenty-four participants were included in the final analyses (19 women; mean age=20,1 years; age range=18 to 24 years). Six participants were excluded because of excessive eye movement artefacts, apparatus failure, or because they made too many errors on the comprehension questions (see below). All participants had normal or corrected-to-normal vision, had no language disability, and had no psychological or neurological impairment. The study was approved by the local ethics committee, and written informed consent was obtained prior to participation. The participants were paid or received course credit.

Stimulus materials and procedure

Visual degradation materials

One hundred eight sentence contexts were created. These contexts were weakly predictive of a critical word (e.g., ‘They do not want the <u>customers</u> to see the mess.’) and were adapted sentences from the low cloze probability correct condition of Van de

Meerendonk et al. (2011) The mean cloze probability of the sentences was 0.10, and the critical words were all plausible continuations of the sentences and had a cloze probability of 0. The critical word in each sentence context could be presented in two ways: visually degraded or not. Visual degradation was accomplished by randomly removing 75% of the pixels from the critical word. A pre-test in which 4 participants read the sentences out loud was conducted to ensure that although degradation made the words more difficult to read, accuracy was high (mean error percentage 2%). The mean length of the sentence and the mean frequency, length and position of the critical word were matched to the plausibility experimental trials (see below).

A pilot study consisting of a self paced reading task with 14 participants (12 women; mean age = 20.1 years; age range = 18 to 25 years) was conducted to check whether the degradation procedure was effective in raising the difficulty of reading the critical words. Each participant saw half of the materials, such that no sentence context was repeated. The results showed that the reading times for the degraded critical words (926 msec) were significantly slower compared to the undegraded critical words (564 msec) ($p<.001$).

The 108 experimental contexts were split in half to ensure that participants would see different contexts in the EEG study and the fMRI study in which they also participated (for the fMRI results, see Van de Meerendonk, Rueschemeyer, & Kolk, submitted). For each half, two experimental lists were created such that the two presentation versions of each context were counterbalanced across lists and participants saw only one version of a sentence. Hence, each list consisted of 27 undegraded and 27 degraded trials. The trials were pseudorandomized in such a way that a certain condition never occurred more than three times in a row, and undegraded and degraded trials were equally often preceded by a undegraded or degraded trial.

Syntactic materials

As for the visual degradation materials, 108 sentence contexts were created for the syntactic condition. Each sentence context had two sentence versions: a syntactic correct and a syntactic incorrect version that contained an agreement violation on the verb (see Table 1 for an example). Half of the sentences contained a critical singular verb and half a critical plural verb. Furthermore, half of the subject noun phrases had animate and half had inanimate referents. The mean length of the sentence and the mean length and position of the critical word were matched to the plausibility experimental trials (see below).

The 108 experimental contexts were split in half, resulting in 54 experimental sentences per list. Four experimental lists were created such that the two sentence versions of each context were counterbalanced across lists and participants saw only one version of a sentence context. Therefore, each list consisted of 27 syntactic correct and 27 syntactic incorrect sentences. The trials were pseudorandomized using the same constraints as for the visual degradation materials. Syntactic correct and incorrect trials were equally often preceded by a syntactic correct or incorrect trial.

Table 1. Examples of the two representational conflict conditions.

Condition	Sentence
Syntactic agreement	
syntactic correct	De schone kleren en handdoeken hangen aan de waslijn te drogen.
	(The clean clothes and towels hang out on the clothesline to dry.)
syntactic incorrect	De schone kleren en handdoeken hangt aan de waslijn te drogen.
	(The clean clothes and towels hangs out on the clothesline to dry.)
Plausibility	
plausible	Het oog bestaande uit onder andere een pupil, iris en netvlies is erg gevoelig.
	(The eye consisting of among other things a pupil, iris and retina is very sensitive.)
mildly implausible	Het oog bestaande uit onder andere een pupil, iris en wenkbrauw is erg gevoelig.
	(The eye consisting of among other things a pupil, iris and eyebrow is very sensitive.)
deeply implausible	Het oog bestaande uit onder andere een pupil, iris en *sticker* is erg gevoelig.
	(The eye consisting of among other things a pupil, iris and sticker is very sensitive.)

Note: The critical word is underlined and the translation is given in parentheses.

Plausibility materials

For the plausibility condition, 99 sentence contexts were taken from a previous study with some minor changes (Van de Meerendonk et al., 2010) and 79 new sentence contexts were constructed in which a word from a certain category was highly expected. The expectancy was created by giving two exemplars of a certain category (e.g., ‘The eye consisting of among other things a pupil, iris and …’). The critical word that complemented the sentence context could be plausible, mildly implausible or deeply implausible, resulting in three conditions for each sentence context (see Table 1 for an example, and Appendix 3 of this thesis).

These 178 sentence contexts were tested in a plausibility judgment task with 42 participants (33 women; mean age = 20.5 years; age range = 18 to 26 years). The sentences were presented till the critical word, and the participants had to rate the plausibility of the sentences on a scale from 1 (very implausible) to 5 (very plausible). To ensure that each participant saw each sentence context only once, three lists were created across which the three sentence conditions were counterbalanced. An equal amount of participants was tested for each list (i.e., 14 participants per list). From this plausibility judgment task 162 experimental sentence contexts were selected. The mean plausibility rating for the plausible, mildly implausible and deeply implausible condition was 4.9, 3.1 and 1.1 respectively. An ANOVA indicated that these differences in plausibility were reliable ($p<.0001$). Follow-up pairwise comparisons between the three plausibility conditions revealed (i) that the plausible condition differed significantly from the mildly and deeply implausible conditions (both $ps<.0001$) and (ii) that a significant difference was present between the mildly and deeply implausible conditions ($p<.0001$).

To obtain a more objective measurement of the plausibility of the critical materials a latent semantic analysis (LSA, see http://lsa.colorado.edu/) was conducted on an English translation of the experimental sentences (see Van de Meerendonk et al., 2010 for the procedure). Twelve trials were excluded from the LSA analysis because no translation could be found for a portion of the nouns. The mean semantic similarity value (SSV) for the remaining 150 trials was 0.36 for the plausible, 0.28 for the mildly implausible, and 0.18 for the deeply implausible sentences. An ANOVA indicated that these differences in mean SSV were reliable ($p<.001$), and this was also reflected in the follow-up pairwise comparisons between the three plausibility conditions (all $ps<.001$). The LSA analysis thus confirmed that the three conditions differed in semantic plausibility.

The three conditions of a sentence only differed in the critical words used. The critical words could be maximally three syllables long and across the three conditions did not differ in mean length ($p>.1$). Furthermore, for each critical word the frequency was searched using the CELEX lemma database (Baayen, Piepenbrock, & Gulikers, 1995), and the mean frequency did not differ across conditions ($p>.1$). The sentences had a mean length of eleven words and the position of the critical word varied across the sentences.

The 162 experimental contexts were split in half, resulting in 81 experimental sentences per list. Six experimental lists were created such that the three sentence versions of each context were counterbalanced across lists and participants saw only one version of a sentence. Consequently, each list consisted of 27 plausible, 27 mildly implausible, and 27 deeply implausible sentences. In addition, 42 out of 84 fillers were added to each list. Of these 84 fillers, 56 sentences did not contain any violation. The remaining 28 sentences contained a semantic violation (e.g., "The pillows are stuffed with books…") and were adapted from Vissers et al. (2006). The trials were pseudorandomized using the following constraints: each list began with two filler trials, filler or experimental trials never occurred more than three times in a row, and violations and a certain condition never occurred more than three times in a row.

Procedure

The stimuli were presented visually using the Presentation software (Neurobehavioral Systems, www.neurobs.com). Participants were tested individually, seated in front of a computer screen in a dimly lit Faraday cage. The sentences were presented in serial visual presentation mode at the center of the screen, with the words in white capitals on a grey background.

The trials began with a fixation cross (510 msec duration) followed by a 500 msec blank screen. Then the sentence was presented; the words had a duration of 350 msec and a stimulus onset asynchrony of 645 msec. Sentence-final words were indicated with a full stop and inter-trial intervals lasted 2000 msec. Participants were instructed to blink between sentences.

To ensure that the participants attentively read the sentences, 10% of the sentences was followed by a comprehension question ('yes/no') about the previous sentence. The participants had to respond by pressing a button with the left index or left middle finger. When the participants pressed a button or failed to respond within 3 sec, the question disappeared from the screen. Questions to which the participants failed to respond within 3 sec were counted as an error.

The presentation of the sentence conditions was divided into 4 runs (1 visual degradation block, 1 syntactic block, and 2 plausibility blocks) with pauses in between. The order of the blocks was counterbalanced across subjects with the provision that the two plausibility blocks always followed each other. This ‘blocked design’, in which the various anomalies were not mixed, was chosen for comparability to our previous studies and because list composition has been found to influence ERP patterns (e.g., Chwilla et al., 2000).

Data acquisition and analysis

The continuous EEG was recorded with 27 electrodes mounted in an elastic electrode cap (Electro-Cap International). The montage included 5 midline and 22 lateral sites (see Figure 1). The left mastoid served as a reference. The electro-oculogram (EOG) was recorded by horizontal EOG electrodes with a right to left canthal montage and vertical EOG electrodes placed below and above the right eye. The ground was placed on the forehead, in between both eyes. Electrode impedance was less than 5 kΩ for the EOG electrodes, and less than 3 kΩ for all other electrodes. The signals were amplified (time constant=8 sec, band pass=0.02–30 Hz) and digitized on-line with a sampling frequency of 200 Hz.

Before the analyses, the signal was re-referenced to the average of the left and right mastoids. EEG and EOG records were examined for artefacts and excessive EOG amplitude (>100 µV) from 100 ms before the onset of the critical word up to 1000 ms following its onset. Contaminated trials were removed and averages were aligned to a 100-msec baseline period preceding the critical word.

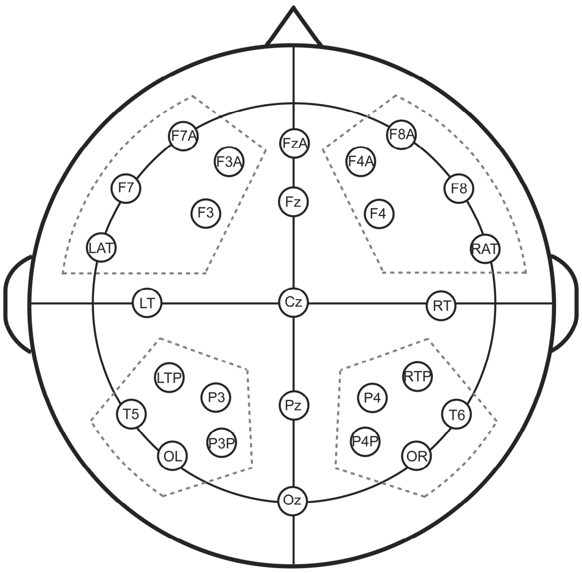

Figure 1. Electrode montage used in the EEG experiment.

For the different conditions, the mean amplitudes were calculated for different time windows, capturing the language relevant ERP components of interest (N400, and P600/late positivity). The choice of these broad time windows was based on a 50 msec time course (TC) analysis, starting from 0-50 msec up to 950-1000 msec measured from critical word onset. To reduce the chance of Type I errors due to the large number of comparisons, at least two consecutive 50 msec time windows had to show a significant effect for a broader time window to be selected. Repeated measures analyses of variance (MANOVAs) were conducted separately for the midline and lateral sites with Degradation (undegraded, degraded), Syntax (correct and incorrect), and Plausibility (plausible, mildly implausible, deeply implausible) as critical factors for the different conditions respectively. Next to these critical factors, the midline analyses included the factor Site (FzA, Fz, Cz, Pz and Oz) and the lateral analyses included the factors Region (anterior, posterior), Hemisphere (left, right) and Site. The factors Hemisphere and Region divided the electrodes into four quadrants: left anterior (F7A, F3A, F7, F3 and LAT), left posterior (LTP, P3, P3P, T5 and OL), right anterior (F8A, F4A, F8, F4 and RAT), and right posterior (RTP, P4, P4P, T6 and OR). Interactions with the factor Site were followed up by paired t-tests at the single-site level. To avoid problems concerning sphericity, the multivariate approach to repeated measures was used (e.g., Vasey & Thayer, 1987). The report of the ERP results will be restricted to the relevant effects including the critical factors.

Results

Performance on the comprehension task

Mean error rate on the comprehension questions was 12.0%. In particular, the error rate for the visual degradation condition was 18.9%, for the syntactic condition 9.4%, and for the plausibility condition 9.8%. Pairwise comparisons indicated that the error rate for the questions of the visual degradation condition was larger compared to the other conditions (both $ps<.01$). These error data are in line with the reaction times of the self-paced reading pilot study, and indicate that the degradation manipulation successfully made the critical words more difficult to read. However, none of the participants made more than 6 errors (25%) in total. The low error percentages indicate that the participants read the sentences attentively.

Event-related potentials

The mean percentage of trials from the visual degradation data that had to be rejected because of excessive EOG amplitude and artefacts was 2.9% for the undegraded and 3.4% for the degraded condition. For the syntactic trials, this was 5.6% for the syntactic correct and 4.0% for the syntactic incorrect condition. For the plausibility trials, 3.9% of the plausible, 5.2% of the mildly implausible, and 5.1% of the deeply implausible condition had to be rejected.

Below, we will present the results of the statistical analyses for the different conditions separately. First, we will present the results for the visual degradation condition. Then we will turn to the results for the two representational conflict conditions.

Visual degradation

The grand-average waveforms for the visual degradation conditions are presented in Figure 2. The TC analysis indicated main effects of Degradation at the midline and lateral sites between 150 and 250 msec (all Fs>6), which corresponds with the latency epoch in which the P2 is typically measured. In addition, a later effect was present at the midline and lateral sites between 300 and 800 msec, peaking at posterior sites at about 500 msec. This later effect, which encompassed the window in which the P600 is typically measured (500-800 msec, see discussion), was reflected in the TC analysis by main effects of Degradation (all Fs>3) and/or interactions of Degradation with Site or Region (all Fs>3). Hence, this early and late time window were selected for further analyses.

For the early window (150-250 msec), the midline analysis yielded a main effect of Degradation [$F(1,23)=13.82$, $p<.01$] and a Degradation x Site interaction [$F(4,20)=10.39$, $p<.001$]. This indicated a more positive P2 amplitude for the degraded compared to the undegraded condition at all midline sites ($ps<.01$) except Oz. At Oz the effect was reversed: the undegraded condition showed a more positive amplitude than the degraded condition ($p<.05$). The lateral analysis yielded a main effect of Degradation [$F(1,23)=15.04$, $p<.01$], and interactions of Degradation x Site [$F(4,20)=8.94$, $p<.001$] and Degradation x Hemisphere x Region [$F(1,23)=6.24$, $p<.05$]. Separate analyses per quadrant indicated a main effect of Degradation and a Degradation x Site interaction at the left and right anterior quadrant (ps.<.05). At the left and right posterior quadrant, no

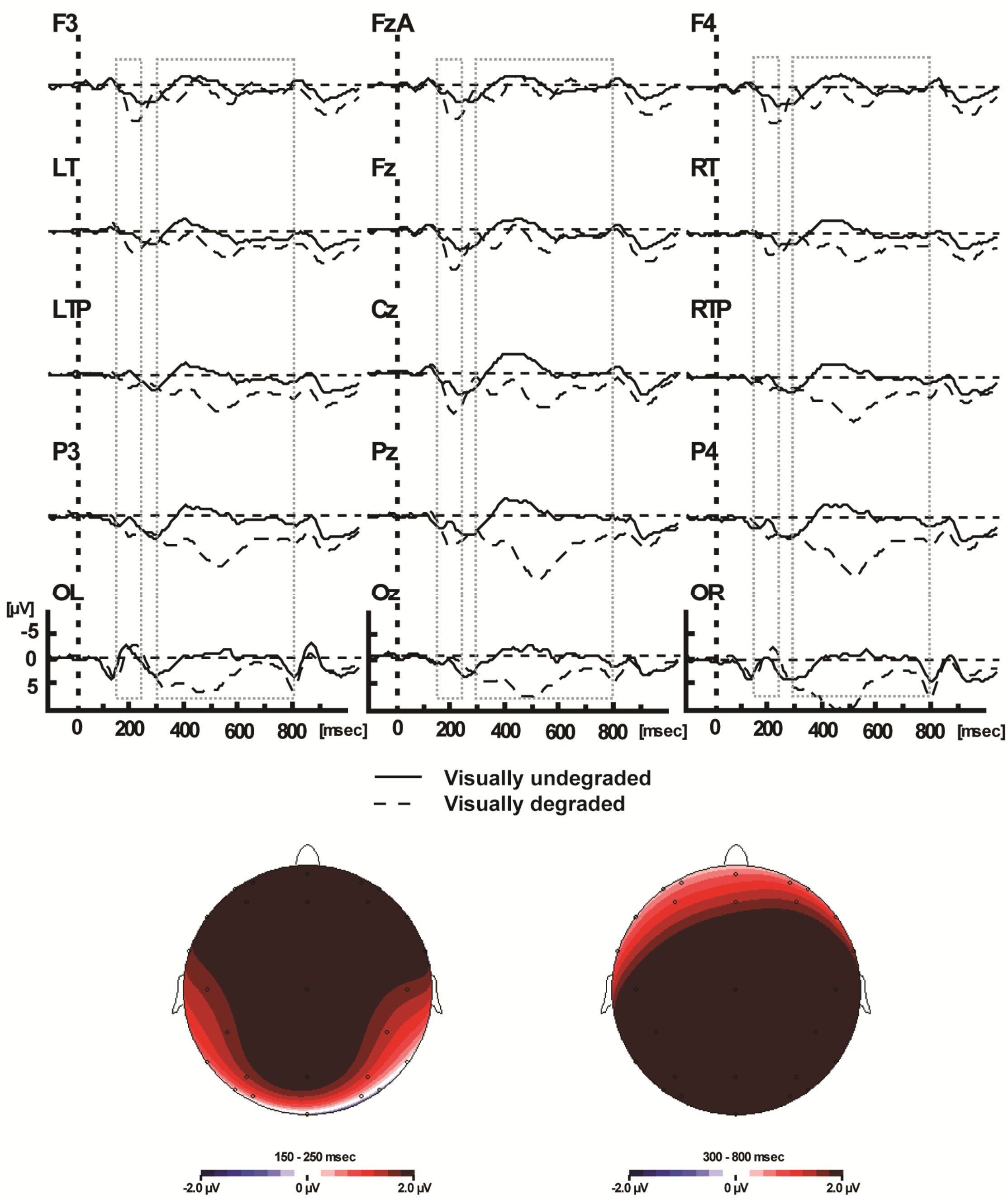

Figure 2. Grand-average ERP waveforms to the critical words for all midline and a subset of lateral sites, for the undegraded and degraded conditions. The dotted rectangles indicate the time windows in which significant differences between conditions were present. The early time window (150-250 msec) corresponds with the latency epoch in which the P2 is typically measured. In a later time window (300-800 msec) a long-lasting positivity occurred with larger mean amplitude for the visually degraded vs. undegraded condition. The topographical maps were obtained from interpolation from 27 sites for these two time windows. The maps were computed from the difference waves of the degraded vs. undegraded condition.

main effect of Degradation was found ($F<1$), but an interaction of Degradation x Site was present ($ps<.05$). Single site analyses indicated that the P2 amplitude was more positive for the degraded condition at all anterior sites, and for a subset of posterior sites (LTP, P3, P3P, and OR ($ps<.01$)).

For the later time window (300-800 msec) a significant main effect of Degradation [$F(1,23)=29.07$, $p<.001$] and a Degradation x Site interaction [$F(4,20)=12.93$, $p<.001$] were found for the midline sites. This reflected that at Cz, Pz, and Oz mean amplitude for the degraded condition was more positive than for the undegraded condition ($ps<.001$). At the lateral sites, a main effect of Degradation [$F(1,23)=30.42$, $p<.001$], and an interaction of Degradation x Region x Site [$F(4,20)=7.10$, $p<.01$] were present. A separate analysis of the anterior region yielded a Degradation x Site interaction ($p<.05$). For the posterior region, there was a main effect of Degradation ($p<.001$) and a Degradation x Site ($p<.001$) interaction. These results in the late time window showed that at all left and right posterior sites ($ps<.001$) and one right anterior site (RAT, $p<.05$) mean amplitude was more positive going for the degraded compared to the undegraded condition.

Representational conflict

Syntactic agreement violations

The grand-average waveforms for the syntactic conditions are presented in Figure 3. The TC analysis revealed interactions of Syntax x Site between 500 and 700 msec at the midline (all $Fs>3.5$), indicative of a small P600 effect for the syntactic incorrect condition. At the lateral sites interactions of Syntax x Region were present between 500 and 600 msec (all $Fs>8$), but separate analyses per region did not show significant effects. Therefore, based on the TC analysis for the midline, a time window from 500-700 msec was selected for further analyses.

In this time window (500-700 msec), the midline analysis yielded a Syntax x Site interaction [$F(4,20)=4.82$, $p<.01$]. Single site analyses indicated an increased amplitude for the syntactic incorrect compared to syntactic correct condition at Fz only ($p<.05$). The lateral analysis did not yield significant results. The absence of a P600 effect came as a surprise, since syntactic agreement violations have been shown to reliably elicit P600

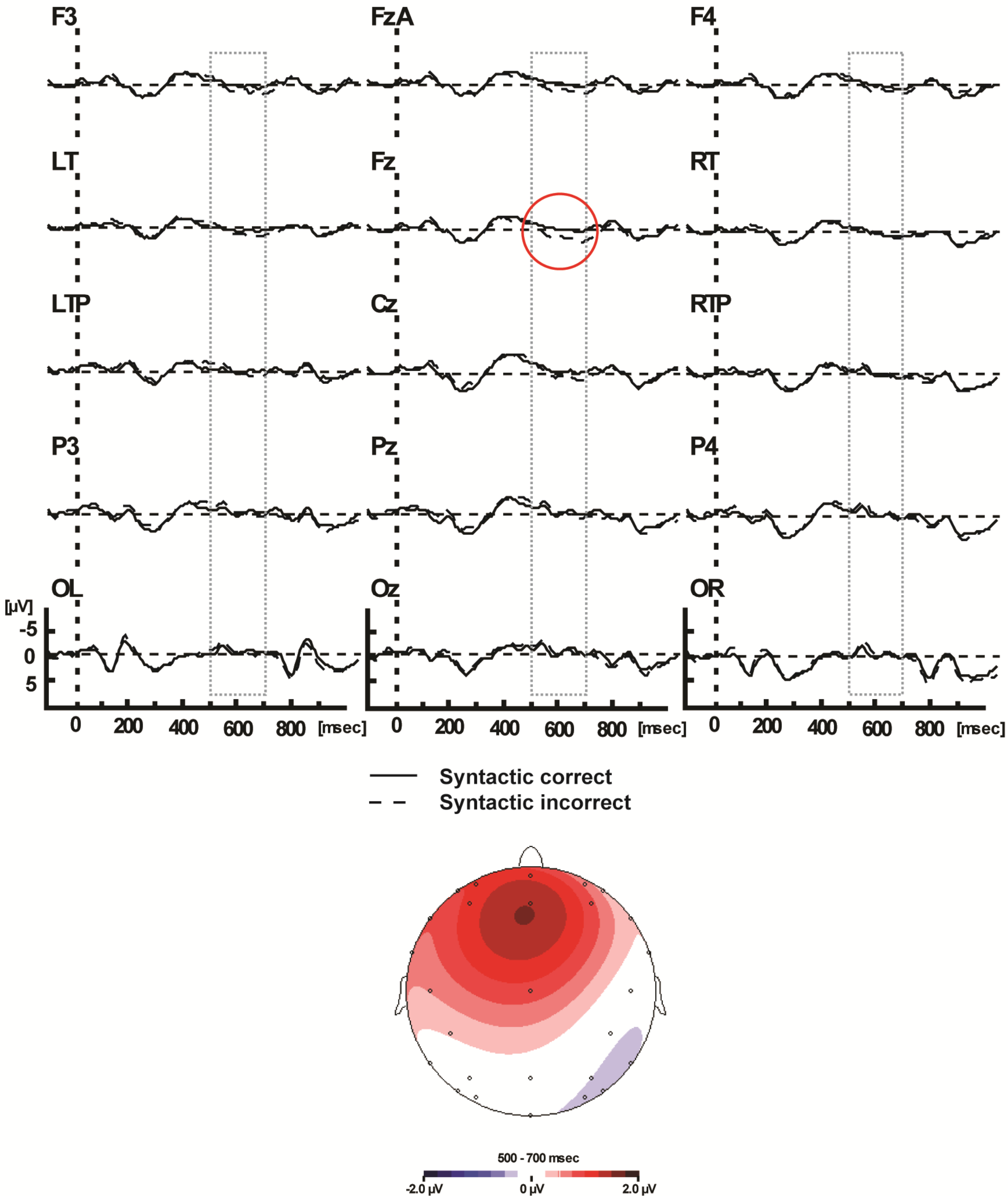

Figure 3. Grand-average ERP waveforms to the critical words for all midline and a subset of lateral sites, for the syntactic correct and incorrect conditions. The dotted rectangle indicates the time window in which the P600 (500-700 msec) was measured. The red circle indicates the only electrode (Fz) where the effect was significant. The topographical map was obtained from interpolation from 27 sites for this time window. The map was computed from the difference waves of the syntactic incorrect vs. syntactic correct condition.

effects (e.g., Hagoort et al., 1993; Osterhout & Mobley, 1995; Van de Meerendonk et al., 2011; Vos et al., 2001). Inspection of the ERP data suggested that presentation order affected the ERP pattern in the syntactic condition. Specifically, whether the participants had seen the visual degradation block before or after the syntactic block appeared to influence the results (see Figure 4). Therefore, supplementary TC analyses were performed for these two presentation orders to select time windows for further analyses.

Syntactic block before visual degradation block. The TC analysis yielded main effects of Syntax between 500 and 850 msec at the midline (all Fs>5.5), and between 550 and 800 msec at the lateral sites (all Fs>5), indicating the presence of a standard P600 effect to syntactic agreement violations. Hence, the 550-800 msec time window was selected for further analyses (see Figure 4a).

The analysis of this time window (550-800 msec) yielded a main effect of Syntax [F(1,11)=12.80, p<.01] and a Syntax x Site interaction [F(4,8)=4.15, p<.05] at the midline sites, indicating a more positive amplitude for the syntactic incorrect compared to syntactic correct condition across the midline (all ps<.05). At the lateral sites, a main effect of Syntax was found [F(1,11)=8.87, p<.05] in the absence of any interactions with Site, Hemisphere, and/or Region. To sum up, for the group who had seen the syntactic block first, a broadly distributed P600 effect was present to syntactic agreement violations.

Visual degradation block before syntactic block. The TC analysis indicated two effects. First, between 50 and 200 msec an increase in an early negativity was present for the syntactic incorrect compared to the correct condition, as reflected by main effects of Syntax for the midline and lateral sites (all Fs>5). Second, the TC analysis revealed main effects of Syntax between 400 and 500 msec at the midline (Fs>10.5), and between 400 and 600 msec at the lateral sites (all Fs>8.5), indicating differences in N400 amplitude between conditions. Hence, for further analyses, an early (50-200 msec), and later time window (400-500 msec) were selected (see Figure 4b).

For the early window (50-200 msec), a main effect of Syntax at the midline and lateral sites was found [F(1,11)=11.04, p<.01 and F(1,11)=18.43, p<.01, respectively].

This indicated that syntactic agreement violations elicited an early negative shift with a broad scalp distribution.

For the later window (400-500 msec) a main effect of Syntax [$F(1,11)=5.44$, $p<.05$] and a Syntax x Site interaction [$F(4,8)=3.89$, $p<.05$] were found at the midline sites. Furthermore, a main effect of Syntax [$F(1,11)=6.72$, $p<.05$] was obtained at the lateral sites. These effects indicated that at Cz, Pz, Oz (ps<.05) and across the lateral sites N400 amplitude was more negative going for syntactic incorrect compared to syntactic correct condition.

Thus, instead of showing a P600 effect to syntactic agreement violations, the group of participants who had first seen the visual degradation condition showed an N400 effect which was preceded by an early negative shift.

Plausibility violations

The grand-average waveforms for the plausibility conditions are presented in Figure 5. In the TC analysis, pairwise comparisons of the *mildly implausible vs. plausible* and *deeply implausible vs. plausible* conditions indicated main effects of Plausibility between 300 and 550 msec for the midline and lateral sites (all Fs>4). Furthermore, a late effect was present between 700 and 1000 msec, as reflected by interactions of Plausibility x Site at the midline for the *deeply implausible vs. mildly implausible* comparison (all Fs>4), and Plausibility x Region interactions for the *deeply implausible vs. plausible* and *deeply implausible vs. mildly implausible* comparisons (all Fs>4). Hence an early (300-550 msec) and late time window (700-1000 msec) were selected for further analyses.

For the early window (300-550 msec) the omnibus analyses across the three levels of plausibility showed a main effect of Plausibility [$F(2,22)=5.28$, $p<.05$] and a Plausibility x Site interaction [$F(8,16)=3.12$, $p<.05$] for the midline sites. At the lateral sites a main effect of Plausibility [$F(2,22)=7.83$, $p<.01$] and a Plausibility x Region interaction [$F(2,22)=4.95$, $p<.05$] were present. The omnibus analyses for the late window (700-1000 msec) yielded a Plausibility x Site interaction for the midline sites [$F(8,16)=5.52$, $p<.01$], and a Plausibility x Region interaction [$F(2,22)=9.98$, $p<.01$] for the lateral sites.

For both time windows, follow-up planned simple effect MANOVAs were conducted to make comparisons between all pairs of plausibility conditions.

(a) Syntactic block before visual degradation block

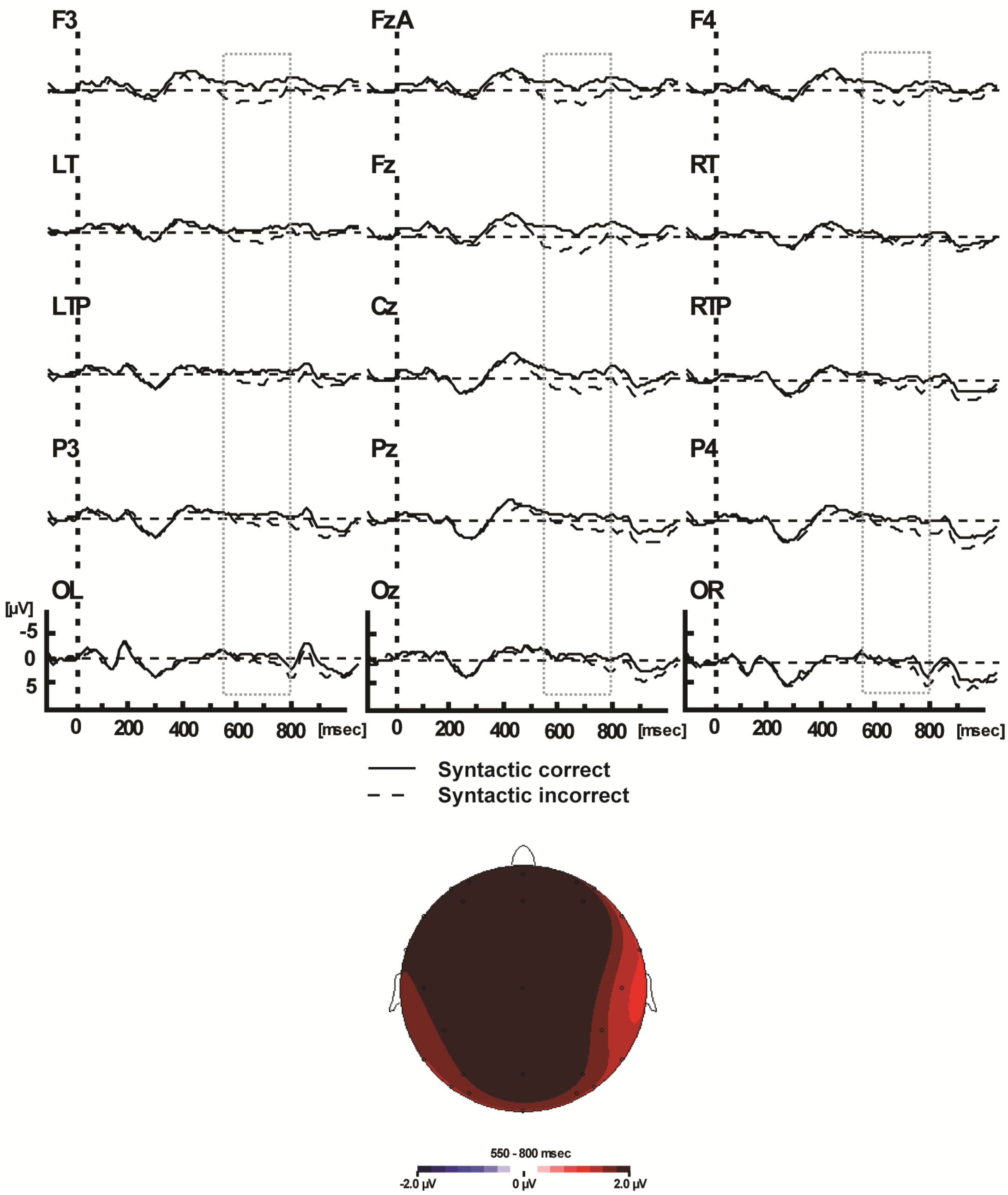

Figure 4a. Grand-average ERP waveforms to the critical words for all midline and a subset of lateral sites, for the syntactic correct and incorrect conditions split up for the two presentation orders. The dotted rectangles indicates the time windows in which significant differences between conditions were present. (a) Participants who had seen the syntactic block before the visual degradation block showed an increased amplitude to the incorrect condition between 550-800 msec, indicating a P600 effect.

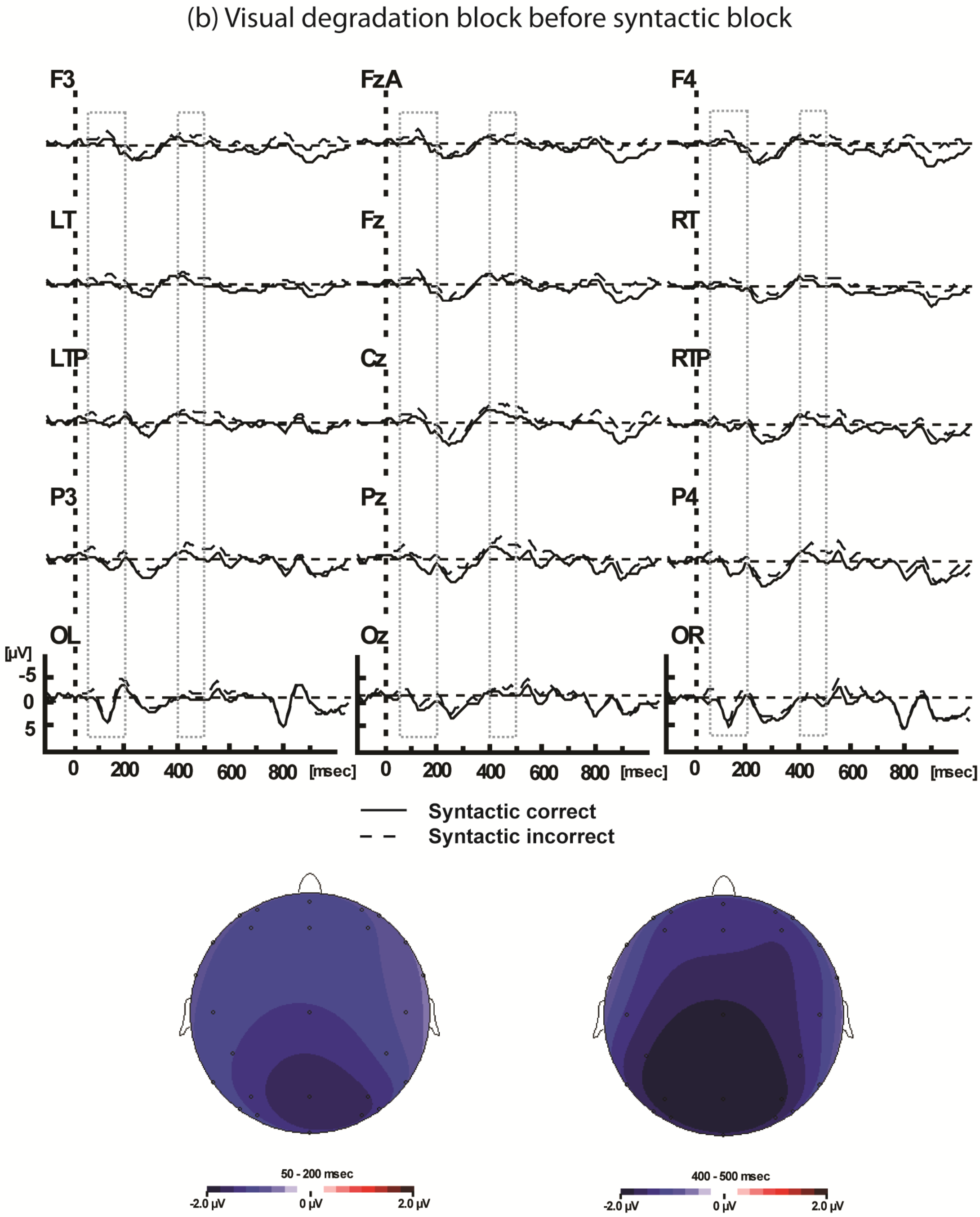

Figure 4b. (b) For participants who had seen the visual degradation block before the syntactic block, the incorrect condition elicited an early negative effect (50-200 msec), and a later negative effect (400-500 msec) indicating an N400 effect. The topographical maps were obtained from interpolation from 27 sites for these time windows. The maps were computed from the difference waves of the syntactic incorrect vs. syntactic correct condition.

Mildly implausible vs. plausible condition. In the early window (300-550 msec) a main effect of Plausibility [F(1,23)=6.81, p<.05] and an interaction of Plausibility x Site [F(4,20)=3.75, p<.05] were obtained at the midline, indicating the presence of an N400 effect for the mildly implausible condition at Cz, Pz and Oz (ps.<.01). The lateral analysis showed a main effect of Plausibility [F(1,23)=7.63, p<.05] and an interaction of Plausibility x Region [F(1,23)=9.29, p<.01]. Separate analyses of the anterior and posterior regions yielded a main effect of Plausibility at the posterior sites (p<.01) but not at the anterior sites (F<2). These results indicated that an N400 effect was present for the mildly implausible condition at posterior sites.

For the late time window (700-1000 msec) an interaction of Plausibility x Site [F(4,20)=6.17, p<.01] was found for the midline sites. The lateral analysis showed a Plausibility x Region [F(1,23)=8.14, p<.01] and a Plausibility x Site interaction [F(4,20)=2.98, p<.05]. Follow-up analyses of the midline and lateral sites, however, did not result in significant effects of Plausibility.

Deeply implausible vs. plausible condition. For the early window (300-550 msec), a main effect of Plausibility [F(1,23)=10.14, p<.01] and an interaction of Plausibility x Site [F(4,20)=3.63, p<.05] were present at the midline sites. The latter interaction reflected that an N400 effect was present for the deeply implausible condition at all midline sites (ps.<.05), except from Oz where the effect was marginal (p=0.052). At the lateral sites a main effect of Plausibility [F(1,23)=15.29, p<.001] was found in the absence of any interactions. This indicated that the N400 effect for the deeply implausible condition was widely distributed across the scalp.

The midline analysis of the late time window (700-1000 msec) yielded no significant results. The lateral analysis indicated a Plausibility x Region interaction [F(1,23)=10.00, p<.01]. Separate analyses for the anterior and posterior regions indicated a main effect of Plausibility for the posterior region (p<.05) but not for the anterior region (F<0.5). These results showed that at bilateral, posterior sites the deeply implausible condition elicited an increased positivity, resembling a P600 effect.

Deeply implausible vs. mildly implausible condition. The midline and lateral analyses of the early time window (300-550 msec) did not yield any significant main effects of Plausibility or relevant interactions with this factor, indicating that no difference in N400 amplitude between the mildly and deeply implausible conditions were present.

For the late time window (700-1000 msec) an interaction of Plausibility x Site [$F(4,20)=7.53$, $p<.01$] was found for the midline sites. Single-site analyses showed that at Pz and Oz the amplitude was more positive going for the deeply implausible compared to the mildly implausible condition (ps<.05). The lateral sites yielded an interaction of Plausibility x Region [$F(1,23)=20.57$, $p<.001$] and Plausibility x Site [$F(4,20)=3.69$, $P<.05$]. Separate analyses for the anterior and posterior regions, indicated no significant effects at the anterior region (Fs<3). At the posterior region there was a main effect of Plausibility ($p<.05$), and interactions of Plausibility x Site ($p<.05$) and Plausibility x Hemisphere x Site ($p<.01$). Further analyses of the left and right posterior quadrants showed a main effect of Plausibility for the left posterior quadrant ($p<.05$), indicating a more positive amplitude for the deeply implausible condition. For the right posterior quadrant there was an interaction of Plausibility x Site ($p<.01$). Single site analyses for the right posterior sites revealed a significant effect at P4P ($p<.05$), and marginal effects at P4 ($p=.066$) and OR ($p=.060$). Taken together, these results showed a posteriorly distributed positivity, resembling a P600 effect, for the deeply compared to the mildly implausible condition which was mainly constrained to the left hemisphere.[16]

[16] We also checked whether presentation order affected the results of the plausibility conditions. In contrast with the results for the syntactic conditions, for the plausibility conditions the only indication for a difference between groups was in the early time window (300-550 msec). In this time window the omnibus analyses showed a Plausibility x Region x Hemisphere x Order interaction at the lateral sites [$F(2,21)=3.86$, $p<.05$]. Separate pairwise comparisons of all plausibility conditions only showed a trend for a Plausibility x Hemisphere x Order interaction ($p=0.052$) when comparing the mildly implausible with the plausible condition. Separate analyses for each group indicated that the participants who had seen the visual degradation block before the plausibility block elicited a broadly distributed N400 effect to the mildly implausible condition (main effects of Plausibility at the midline and lateral sites, both ps<.05). This N400 effect was more restricted to the posterior sites for the group of participants who had seen the plausibility block before the visual degradation block (only the left and right posterior quadrants showed a main effect of Plausibility, both ps<.05).

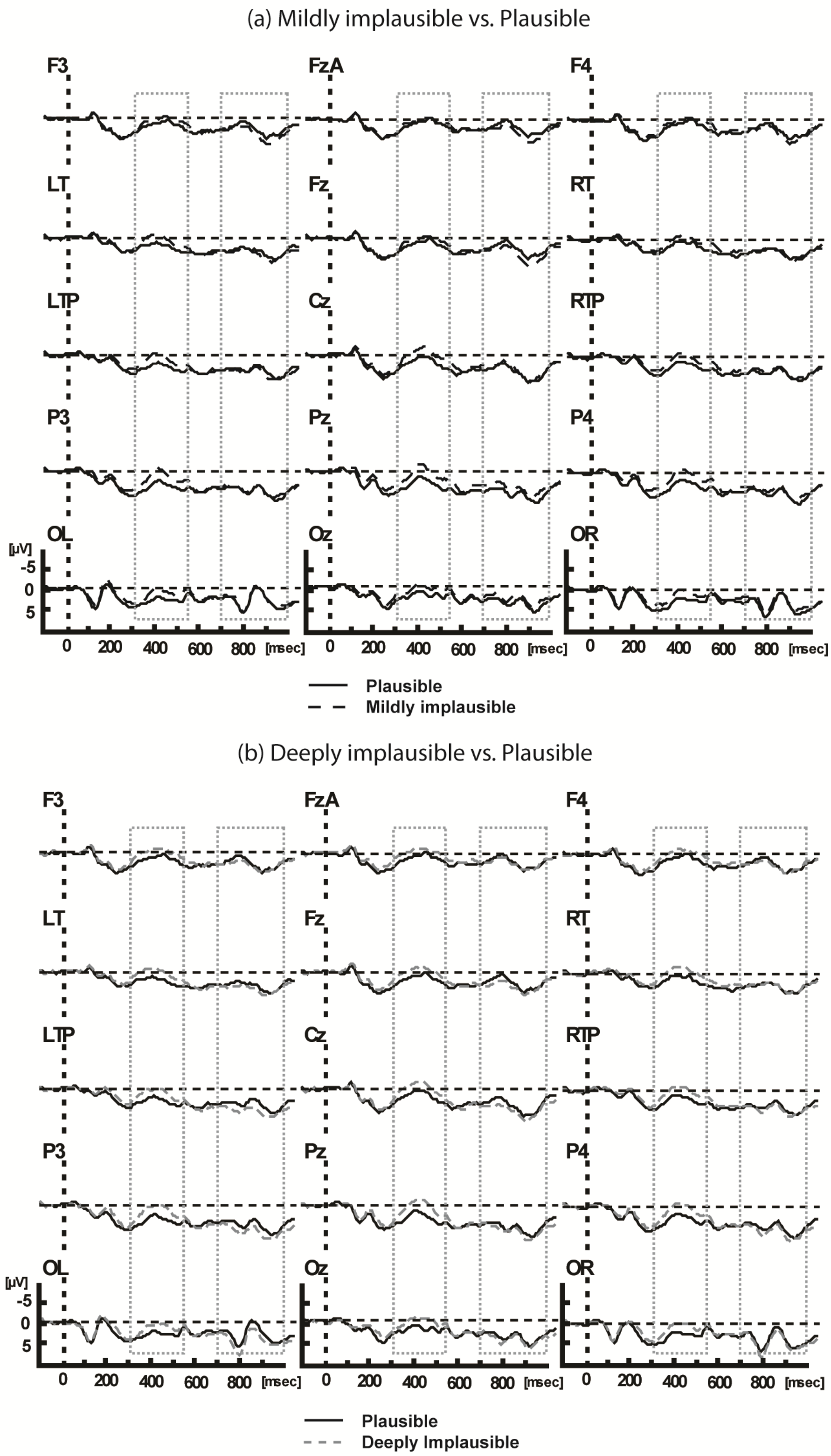

Figure 5a & 5b. Grand-average ERP waveforms to the critical words for all midline and a subset of lateral sites, for the pairwise comparisons: (a) mildly implausible vs. plausible; (b) deeply implausible vs. plausible. The dotted rectangles indicate the time windows in which significant differences between conditions were present. In the early time window (300-550 msec) an N400 effect was indicated for the implausible conditions. In the late time window (700-1000 msec) the deeply implausible condition showed an increased posterior positivity compared to the plausible conditions, resembling a P600 effect.

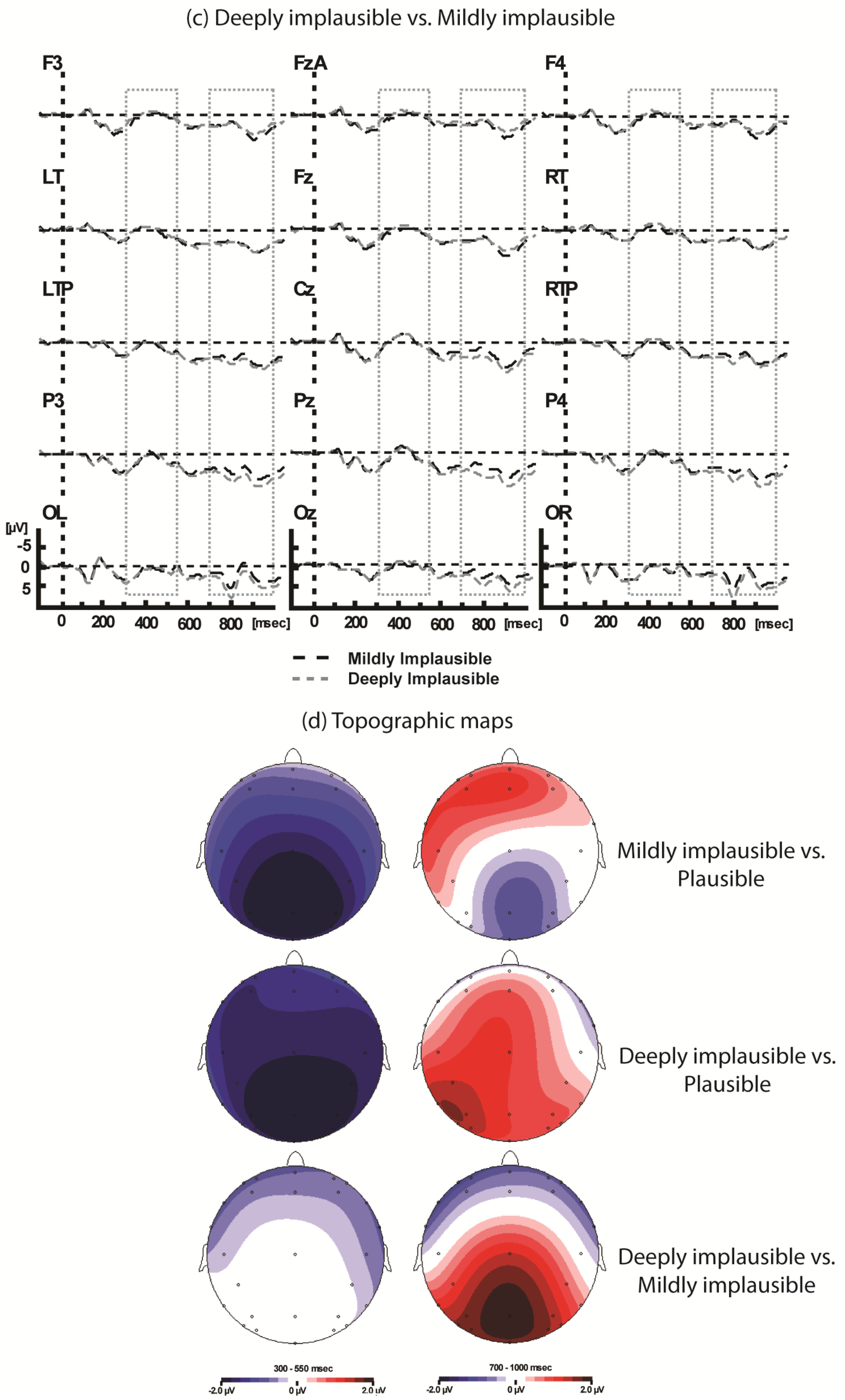

Figure 5c & 5d. (c) deeply implausible vs. mildly implausible. In the early time window (300-550 msec) no difference was present when comparing the mildly with the deeply implausible condition. In the late time window (700-1000 msec) the deeply implausible condition showed an increased posterior positivity compared to the mildly implausible condition, resembling a P600 effect. In (d) the topographical maps of all pairwise comparisons are given, obtained from interpolation from 27 sites for both time windows. The maps were computed from the difference waves of the respective conditions.

Discussion

The present study compared the ERP response to a lack of bottom-up information due to visual degradation of words in a sentence, with the ERP response to representational conflicts in visual language perception. Representational conflicts at different levels of linguistic description (e.g., syntactic, semantic, and orthographic levels) have been found to elicit a late positivity or P600 effect (Kolk et al., 2003; Van de Meerendonk et al., 2011; Van de Meerendonk et al., 2010; Van Herten et al., 2006; Van Herten et al., 2005; Vissers et al., 2006; Vissers et al., 2008). According to the monitoring theory of language perception the P600 is triggered by a conflict monitoring mechanism which signals that adjustments in control are needed. In particular, when there is a strong mismatch between an expected and observed linguistic element, this induces a conflict which brings the language system into a state of indecision ('Did I read that correctly?'). The conflict functions as a bottom-up signal to bias attention towards the unexpected element and triggers reprocessing of the input to check for possible processing errors. This monitoring process is thought to be reflected by the P600 effect (for reviews, see Kolk & Chwilla, 2007; Van de Meerendonk et al., 2009; but see e.g., Kim & Osterhout, 2005; Kuperberg, 2007 for different accounts on the P600 effect).

Conflict monitoring, however, is just one of the mechanisms to evaluate the demands for control. In the present study we investigated whether another type of cognitively demanding input in visual language perception, namely the situation in which a word is difficult to read, could also signal that adjustments in control are needed. Although in this situation no conflict between an expected and observed linguistic element is present, extra attention is needed to facilitate word identification. Hence, the aim of the present study was to investigate whether the language user deals with this type of problem, namely a lack of bottom-up information, in a similar way as in the case of representational conflicts. To this end, the ERP effects of visually degrading a word in a sentence were examined, and compared with two types of representational conflict conditions: syntactic agreement violations and plausibility violations. In particular, we tested whether visual degradation would also trigger a monitoring response and elicit a positivity in the P600 window, as in the case of a representational conflict.

The main results for the three conditions were as follows. First, compared to the undegraded condition, the degraded condition elicited a long-lasting central-posterior positivity from 300-800 msec, which encompassed the P600 window. Compared with previous ERP studies that investigated visual degradation, this positivity could be related to either the P300 and/or late positivities that were found in these studies (Chwilla & Brunia, 1991; Kok & Looren de Jong, 1980; Ruchkin et al., 1988). We will come back to this issue below, when we compare the various positivities that were elicited by a lack of bottom-up information vs. representational conflicts. Furthermore, preceding this long-lasting positivity, the degraded condition elicited an increased P2 amplitude which was broadly distributed, and tended to be larger at anterior and central sites. P2 amplitude modulations have been found in visual search tasks, where they have been linked to the detection and analysis of visual features. In these tasks, the P2 amplitude is larger for stimuli containing target features, and the effect is enhanced for relatively infrequent targets (e.g., Luck & Hillyard, 1994). In line with these findings, the increase in P2 amplitude is taken to index enhanced visual analysis of the degraded words.

Second, upon first analysis of the syntactic condition, the agreement violations did not show the standard P600 effect which is generally observed (e.g., Hagoort et al., 1993; Osterhout & Mobley, 1995; Van de Meerendonk et al., 2011; Vos et al., 2001). Additional analyses that will be discussed in more detail below, revealed that the order in which participants had seen the syntactic and visual degradation block gave rise to different ERP patterns.

Third, in accordance with the study by Van de Meerendonk et al. (2010), the mildly and deeply implausible sentences elicited different ERP patterns when compared to plausible sentences. While mildly implausible sentences elicited a monophasic N400 effect, deeply implausible sentences elicited a biphasic N400-P600 pattern.

In the following paragraphs the results will be discussed in more detail. We will first consider the presentation order effect that was found to influence the ERP patterns to syntactic agreement violations, and suggest a possible explanation. Second, we will compare the positivities that were elicited by visual degradation vs. representational conflicts, and discuss how they could be related.

Presentation order affects ERP pattern to syntactic agreement violations

The ERP results of the syntactic condition were unexpectedly influenced by whether participants had seen the visual degradation block before or after the syntactic block.

Participants who had seen the syntactic block first, showed a standard P600 effect to syntactic agreement violations. In contrast, participants who had seen the visual degradation block first, revealed an N400 effect to the syntactic agreement violations, which was preceded by an early negative effect between 50-200 msec. The early negative effect could be a reflection of the early left anterior negativity (ELAN), which usually occurs between 100-300 msec after a word category violation and is thought to index initial automatic processes of syntactic structure building (e.g., Friederici et al., 1993). However, the present study investigated agreement violations, and the early negative effect that was elicited had a broad scalp distribution. Therefore, we think it is unlikely that the early negative effect is a reflection of an ELAN, and hence the functional significance of this early effect remains unclear. That is why in the remainder, we will focus on explaining the differential finding of a standard P600 effect versus an N400 effect to syntactic agreement violations.

A possible post-hoc explanation for this difference in ERP pattern could be the following. In the visual degradation condition, the participants were confronted with a lack of bottom-up information. Because the sentences were weakly constraining, no expectation for a certain word could be formed, and the participants had to concentrate on identifying the degraded word to be able to incorporate it into the sentence context. Once the word was identified, however, it could be integrated into the sentence context without any difficulty, because it was a semantically plausible continuation of the weakly constraining sentence that did not contain a violation of any kind. Therefore, in the visual degradation condition participants invested extra attention to complete the degraded representation, but the resulting integration process was successful. These 'successful experiences' might have subsequently influenced how participants processed the syntactic agreement violations. In the syntactic condition the critical words were not degraded. Therefore, when participants encountered a syntactic agreement violation they did not feel they had to check whether they had read the word correctly and reprocessing of the input was not needed, hence no P600 effect was elicited. Instead of such a monitoring response, they might have taken the information for granted, and tried to integrate the verb into the sentence. Exploiting such a semantic strategy makes sense as the default mode in everyday life is to process words for meaning. The agreement violation, however, was detected and caused integration problems, as reflected by the presence of an N400 effect.

A previous study that also reported N400 as well as P600 effects to syntactic anomalies is the study by Osterhout (1997). While syntactic ambiguities in the latter study elicited a P600 effect in most participants, some participants showed an N400 effect instead. Osterhout (1997) proposed that these differences could have arisen from individual differences in processing strategies. Participants that showed a P600 effect might be more sensitive to the syntactic consequences of an ambiguous parse, thereby triggering reprocessing. In contrast, participants that showed an N400 effect might be less likely to reprocess the ambiguity because they are more receptive to problems that the ambiguity causes at the semantic level. In accordance with the study by Osterhout (1997) and the present study, other studies have also indicated that for example individual differences, list composition and the experimental environment can influence processing strategies, thereby affecting ERP components such as the N400, P300 and P600 (e.g., Chwilla et al., 2000; Roehm, Bornkessel-Schlesewsky, Rösler, & Schlesewsky, 2007; Vissers et al., 2007).

However, a question concerning the explanation that different processing strategies might have arisen due to the order of the visual degradation block, is why the overall ERP patterns in the plausibility block were not influenced by this order? Independent of the presentation order of the visual degradation and plausibility block, the mildly implausible condition elicited an N400 effect, while the deeply implausible condition elicited a biphasic N400-P600 pattern. If certain strategies develop during the visual degradation block, why then did they not affect the ERP patterns in the plausibility conditions? We suggest that this relative indifference of the plausibility results arises, because the strategy used to resolve the implausibilities is already to ‘take the information for granted’ and to try and integrate the implausible words in the sentence context. In the case of the mildly implausible condition this integration succeeds, but does give some problems as reflected by the N400 effect. In the case of the deeply implausible condition, however, integration is not successful and reprocessing is needed, eliciting a P600 effect. Note that, although the overall patterns were not affected by the presentation order, the N400 effect in the mildly implausible condition had a broader distribution when the visual degradation block preceded the plausibility block. This result could indicate that additional neuronal populations contributed to the N400 effect in this case. A task for future studies is to further disentangle the consequences of experimental design and individual differences on processing strategies and how these affect ERPs.

Positivities elicited by visual degradation vs. representational conflict

Both the representational conflict conditions (i.e., syntactic agreement violations and deeply implausible words) and the visually degraded words elicited long-lasting positivities in the EEG. These positivities varied in their time-courses. Specifically, the positivity elicited by the visual degradation condition started earliest (around 300 msec), followed by the syntactic condition (around 500 msec), and the deeply implausible condition (around 700 msec). Furthermore, although in general the positivities were present central-posteriorly, their specific topographies showed some variation. While the positivity for the deeply implausible condition was most pronounced at the left central-posterior region, the positivity in the visual degradation condition was more widespread across the central-posterior region. In addition, next to the central-posterior region, the positivity elicited by the syntactic agreement violations also extended to the anterior region.

These variations in onset and scalp topography could be taken to indicate that the various positivities reflect different processes. However, it must be noted that quite some variability in onset and scalp distribution has been reported for P600 effects in sentential studies. Although the P600 is often measured between 500-800 msec, earlier onsets have also been found, for example, around 345 msec in the case of disambiguating auxiliaries (Mecklinger, Schriefers, Steinhauer, & Friederici, 1995). Later onsets have been reported as well, for instance, in a discourse coherence study by Nieuwland and Van Berkum (2005) a later positivity between 700-1300 msec after anomalous continuations was indicated. Accordingly, with regard to the P600, Kutas, Van Petten and Kluender (2006) point out that: "*…it can onset as early as 200 ms (following another positive component – the P200) and often appears as a long-lasting positive shift with no clear peak.*" (p692). Furthermore, although a central-posterior scalp distribution is often found, a more anterior or broad topography has also been reported, for example in the case of ambiguous sentences (Hagoort, Brown, &

Osterhout, 1999), complex sentences (Kaan & Swaab, 2003), spelling violations (Vissers et al., 2006), and picture-sentence mismatches (Vissers et al., 2008).

One proposal in the language comprehension literature is that the P600 reflects a domain-general process elicited by unexpected informative events. More specifically, it has been proposed that the P600 belongs to the same family of P300 components as the P3b, which is elicited by rare nonlinguistic events (e.g., Coulson et al., 1998; Gunter et al., 1997; but see Osterhout, 1997; Osterhout et al., 1996 for counterarguments). According to this proposal, the increased amplitude of the positivities reflects the way that individuals update their mental models of the environment when unexpected information is encountered (e.g., Coulson et al., 1998; Donchin & Coles, 1988). Consistent with this view we propose that the current findings of variations in onset and scalp distribution of the positivities do not reflect different processes: we also suggest that the general process underlying these positivities is the same. However, in accordance with the monitoring theory of language perception (for reviews, see Kolk & Chwilla, 2007; Van de Meerendonk et al., 2009), instead of assuming that unexpected (or a lack of) information leads to updating of the mental model, we propose that it signals a need for adjustments in attentional control to check for possible processing errors or – as in the case of degradation – to identify the word. Depending on the type and complexity of the information that interrupts comprehension and that needs to be reprocessed or identified, the positivities could vary in their onsets and/or scalp distributions (see also Van de Meerendonk et al., 2010; Vissers et al., 2008). For instance, the latency difference between the P600 and P3b to rare nonlinguistic events could be explained by higher complexity of linguistic stimuli. Furthermore, it is likely that visually degraded stimuli trigger an earlier monitoring response (as reflected by an earlier onset around 300 msec) than undegraded violations where the word first has to be read to encounter the anomaly. In addition, the type of stimuli (e.g., semantic or syntactic anomalies, degraded words, etc.) could influence which specific brain regions become involved in the reprocessing or identification of a representation, and this might influence the scalp distribution.

This proposal implies that the process underlying the positivities in the present study should not be interpreted in terms of linguistic processing (e.g., syntactic reanalysis or repair), but in terms of cognitive control. Both the syntactic and plausibility conditions and the visual degradation condition disturb the language comprehension process, either by eliciting a conflict between an expected and observed representation or by creating a temporary lack of information. Thereby, they bring the language system into a state of indecision ('Did I read that correctly?'/'What does it say?'), and signal the need for adjustments in attentional control. In the case of the syntactic and plausibility violations adjustments in control are needed to reprocess the input and bias one of the representations. In the case of the visual degradation condition, allocation of extra attention to the degraded word, facilitates its identification. This monitoring process of evaluating the demands for control is thought to underlie the different positivities, elicited by either a representational conflict or a lack of bottom-up information, in the present study.

The present findings therefore call for an extension of the monitoring theory of language perception: next to strong representational conflicts, which have been shown to reliably elicit P600 effects at different levels of the language comprehension system, a lack of bottom-up information can also give rise to a late positivity. However, it must be noted that, besides strong conflicts between an expected and observed linguistic element – as is the focus of the monitoring theory of language perception – another type of conflict namely the case of 'underdetermined response conflict' has also been reported in the literature. In the case of underdetermined response conflict, competition between multiple weakly activated representations is thought to be present. An example of a task that gives rise to this type of conflict is the category fluency task in which participants for instance have to name as many exemplars of the category 'fruits'. Since all exemplars within this category are equally valid they elicit so called underdetermined response conflict (see e.g., Botvinick et al., 2001; Novick et al., 2009; Thompson-Schill et al., 2005). The visual degradation condition in the present study might create a similar type of conflict, because degraded words may give rise to several weakly activated representations since the words are difficult to read. Underdetermined response conflict, however, would differ from the representational conflicts elicited by syntactic agreement violations and plausibility violations, where there is a strong conflict between two incompatible representations: one stemming from an expected linguistic element and the other from an encountered violation. Although with the data at hand the presence of an underdetermined response conflict cannot be excluded, it seems less likely that the same kinds of control adjustments would be demanded. We therefore assume that what underlies the state of indecision in the visual degradation condition is the lack of bottom-up information.

Previous studies that investigated visual degradation of single letters or numbers in discrimination or mathematical tasks, also reported increased amplitudes of late positivities. These positivities also varied in their time-courses (e.g., onsets before, around or after 500 msec, time windows from 700-800 or 800-1300 msec), and scalp distribution – although the distribution was mainly central-posterior (e.g., Chwilla & Brunia, 1991; Kok & Looren de Jong, 1980; Ruchkin et al., 1988). These late positivities were interpreted in terms of 'continued processing', which is invoked when the cognitive demands of a task increase, and is thought to be associated with the recruitment of mental effort required by the task. This interpretation bears resemblance to our proposal that various cognitively demanding inputs can interrupt comprehension, thereby signaling the need for adjustments in control, which in the case of degraded stimuli leads to extra attention for identification. In particular, both views assume that cognitively demanding stimuli signal the need for some form of extra processing: one formulates this extra processing in terms of mental effort, the other in terms of attentional control. A possible connection could come from Kahneman (1973), who suggested that mental effort refers to the process of the allocation of extra attention, which is recruited when the cognitive demands of a task increase.

Conclusion

The findings in the present article indicate that, next to representational conflicts, a lack of bottom-up information can also hamper language comprehension and bring the system into a state of indecision, thereby eliciting a late positivity in the EEG. We propose that a general monitoring process, which evaluates the demands for control, underlies these positivities. In the case of syntactic agreement violations and deeply implausible continuations, where there is a strong conflict between an expected and observed representation, adjustments in control are needed to bias the unexpected representation by checking the input for possible processing errors. In the case of visually degraded words in a sentence, adjustments in control are required to allocate extra attention to identify the degraded representation.

Chapter 7

Summary and Discussion

As discussed in the general introduction, we usually have no problems to understand each other. Sometimes, however, our understanding is (temporarily) hampered. The studies presented in this thesis, further investigated these problematic situations arising in visual language perception. Central to this investigation is the monitoring theory of language perception. As reviewed in Chapter 2, the monitoring theory of language perception proposes that a conflict between an expected and an observed linguistic element – a 'representational conflict' – can bring the language system into a state of indecision. It is like asking oneself: Did I read that correctly?'. In language perception such a conflict could stem from two sources: the unexpected element indeed occurred, or a processing error was made. To decide between these two possibilities, reprocessing of the input is needed. According to the monitoring theory of language perception this monitoring process, in which representational conflicts can trigger reprocessing of the input, elicits a P600 effect in the EEG.

In the investigation of this monitoring process in visual language perception, we addressed three main issues. First, in the ERP studies described in Chapter 3 and 4, we examined the influence of conflict strength on the monitoring process. Second, in the fMRI studies of Chapter 4 and 5, the brain mechanism involved in conflict monitoring was investigated, with a specific focus on Broca's area. Third, the fMRI study in Chapter 5 and the ERP study in Chapter 6, explored whether a different kind of problem in language perception, namely a lack of bottom-up information, could also elicit a monitoring response. Below, I will summarize the main findings and conclusions of these studies and address some points of discussion. This will be done separately for each of the three main issues. Subsequently, I will discuss some future challenges.

Manipulating conflict strength

The first main issue that was addressed in the present thesis, was whether the strength of the conflict between an expected and an observed linguistic element could influence the monitoring process. The reasoning behind this question was that it would not be efficient if every representational conflict would result in reprocessing of the input to check for possible errors, since we often encounter information that is a bit unexpected. Therefore, we hypothesized that the conflict between an expected and an observed element should be sufficiently strong – that is, pass a certain threshold – to trigger reprocessing of the input and elicit a P600 effect.

But how to manipulate the strength of the conflict? As discussed, following the monitoring theory of language perception we proposed that the conflict arises due to a mismatch between the linguistic element that we expect, and the element that we actually observe. Therefore, one way to manipulate the strength of the conflict is to keep the expectancy for a certain linguistic element the same, but to vary the degree to which the observed element violates this expectancy. A second way to manipulate conflict strength is the reverse situation in which the expectancy for a certain linguistic element is varied, but the actual observed element is kept the same. In the ERP study presented in Chapter 3 we investigated the first type of conflict strength manipulation. The ERP study of Chapter 4 investigated conflict strength using the second type of manipulation.

In the ERP study of Chapter 3, participants read sentences that created a high expectation for an exemplar from a certain category (e.g., 'The eye consisting of among other things a pupil, iris and…'). These sentences could be continued by either a plausible, mildly implausible or deeply implausible word (e.g., 'retina/eyebrow/sticker'). We hypothesized that the mildly implausible condition, when compared to the plausible condition, would elicit a mild conflict between the expected and the observed element. In contrast, the deeply implausible condition would elicit a stronger representational conflict, since the observed word is semantically farther removed from the expectation than the mildly implausible continuation. Hence, we predicted that only the deeply implausible condition should elicit a strong enough representational conflict to trigger reprocessing and elicit a P600 effect when compared to the plausible condition. In the case of the mildly implausible condition, the representational conflict should not pass the threshold to trigger reprocessing, and participants might try to integrate the unexpected information (e.g., by trying to extend the concept of 'eye' to also encompass 'eyebrow'), eliciting an N400 effect. The results of this study indeed showed that the mildly implausible condition elicited an N400 effect, while the deeply implausible condition elicited a biphasic N400-P600 pattern. These different ERP patterns were replicated in Chapter 6, and they were interpreted as follows. Both the mildly and deeply implausible condition gave rise to integration difficulties, as reflected by the N400 effect. For the mildly implausible sentences, these integration difficulties could eventually be resolved, as reflected by the absence of a P600 effect. For the deeply implausible condition, however, integration failed, and reprocessing of the input was triggered to check for possible processing errors, as reflected by the presence of a P600 effect. To conclude, these ERP results indicated that a strong violation of the expected element is needed to create a conflict that is powerful enough to trigger reprocessing.

As discussed above, in the ERP study of Chapter 4 we manipulated conflict strength in another way. In this ERP study, the expectancy based on the sentence context was varied while the actually observed violation was kept the same. Participants read sentences that could be strongly predictive of a certain word (e.g., 'The pillows are stuffed with...') or sentences in which there was no expectation for a certain word (e.g., 'At that spot there sometimes lie...'). These sentences then could be continued either by a correctly spelled word (e.g., 'feathers') or by a pseudohomophone (i.e., a misspelled word, but with a similar phonology as the correct word – e.g., 'feathurs'). We hypothesized that a misspelling in strongly predictive sentences should elicit a stronger representational conflict, since in these sentences the expectation for a certain word is higher than in weakly predictive sentences. Therefore, we expected that the misspellings in the strongly predictive sentences would elicit a larger P600 effect than the misspellings in the weakly predictive sentences. In addition to the spelling violations, we added sentences containing syntactic agreement violations (e.g., 'The clean clothes and towels hangs…'). Since syntactic agreement violations typically elicit a P600 effect, this condition could be used to investigate whether spelling violations elicit a similar P600 effect. The results of the ERP study showed that misspellings in both the strongly and weakly predictive sentences elicited a P600 effect when compared to their correct controls. This effect was similar to the P600 effect found to syntactic agreement violations, indicating that a qualitatively similar process was involved for spelling violations. The P600 effect to misspellings, however, was modulated by the conflict strength manipulation: the P600 effect to misspellings in the strongly predictive sentences was larger than the P600 effect to misspellings in the weakly predictive sentences. These results were taken to indicate that both misspellings in strongly and weakly predictive sentences gave rise to a sufficiently strong conflict to trigger reprocessing. For the strongly predictive sentences, there is a strong expectancy based on the sentence context, which is in conflict with the encountered misspelling. Although there is no strong expectation for a certain word in the weakly predictive sentences, the word context as such – that is the orthography and phonology of the pseudohomophone – might have generated an expectation for the correct word which mismatched with the misspelling. To conclude, this ERP study showed that the P600 effect can also be affected by manipulating conflict strength by varying the expectancy for a certain element while keeping the encountered element the same.

How to quantify conflict strength?

A question that people have asked me concerning the manipulation of conflict strength, is how we know when a conflict is sufficiently strong to trigger reprocessing? Is there a certain measurement that makes it possible for us to quantify the strength of a representational conflict, and thereby allows us to generate certain hypotheses? Unfortunately, the answer to this question is no; there is no measurement to quantify conflict strength. As we discussed above, in the present thesis we have manipulated conflict strength in two ways. First, we varied the degree to which the expectancy was violated, by varying the plausibility of a sentence continuation. Second, the expectation for a certain element was manipulated by varying the predictive value of the sentences, while the encountered misspelling was kept the same.

However, other variables that have not been investigated in this thesis, could also influence our expectancies and the degree to which they are violated, thereby affecting conflict strength. For instance, next to the sentence context that can generate expectations, the larger (experimental) context could do so as well. As discussed in Chapter 4, Coulson et al. (1998) showed that the proportion of syntactic violations can affect P600 amplitude. When syntactic violations were improbable to occur (20% violations) the P600 amplitude was larger than when they were probable (80% violation). This indicates that the larger experimental context in which a violation occurs can influence our expectations, hence affecting the conflict strength. Another example of how the larger context may influence conflict strength is the study by Hanulíková, Van Alphen, Van Gogh and Weber (in press). They showed that the identity of a speaker can influence the P600 effect to syntactic gender violations. This study indicated that Dutch participants showed a standard P600 effect when listening to gender violations, when these violations were produced by native speakers of Dutch. However, when the same gender violations were produced by non-native (Turkish) speakers with a foreign accent, no P600 effect was elicited. Again, as the Coulson et al. (1998) study indicated, this suggests that we can adjust our expectations based on the situation or experimental context in which certain violations are embedded, and this can affect the conflict strength.

Furthermore, various variables could influence our strategies and the strength of the conflict, thereby affecting the P600 effect. For instance, when a judgment task is present in an experiment, this might strengthen the conflict because it makes the encountered violations more salient perceptually – they are less likely to be missed. As noted in Chapter 2 this could explain why some studies that investigated for instance semantic violations and that used an explicit judgment task found P600 effects, while others that did not use such a task did not. However, as already indicated in Chapter 2, and as we have seen in the ERP studies in the present thesis, an explicit judgment task is not a prerequisite for a P600 effect to occur. Additionally, giving participants certain instructions can also influence their strategies and affect conflict strength. For example, Vissers et al. (2007) reduced the conflict strength by explicitly telling the participants before they took part in the experiment that semantic reversal anomalies were present. The participants were told that they should not be deceived by these reversal anomalies, but they should focus on the syntactic structures as such. This instruction reduced the P600 amplitude to semantic reversal anomalies. Another variable that could influence strategies and conflict strength is the presence of individual differences between participants: a certain representational conflict can be sufficiently strong to trigger reprocessing in one person, but might not do so for another person (see e.g., Osterhout, 1997).

In sum, although a quantitative measurement for conflict strength does (not yet) exist, the studies conducted for this thesis and the various examples mentioned above, indicate that the strength of our expectancies and the extent to which they are violated can play an important role in determining conflict strength.

A finding, that is worth mentioning in this discussion of conflict strength, is the presentation order effect that was found in the ERP study in Chapter 6. Instead of a standard P600 effect, an N400 effect was found to syntactic agreement violations when participants had first seen the visual degradation block. We proposed that the visual degradation condition might have biased a semantic strategy in processing syntactic agreement violations. In the visual degradation condition, participants had to identify the degraded word, but once this was done the words could be integrated without any difficulty. These experiences of eventually being able to successfully integrate the words might have subsequently influenced the processing of syntactic agreement violations. In the syntactic block the words were not degraded, hence the participants did not have to check whether a processing error was made (no P600 effect). Instead, the participants might have taken the unexpected syntactic violations for granted, and tried to integrate them into the sentence (N400 effect). If we relate these findings to conflict strength, the following could be said. For both presentation orders the expectation for a syntactically correct item was the same. In addition, the actually encountered element (i.e., the agreement violation) was also identical. Therefore, supposedly, the conflict strength was similar for both presentation orders. What differed between the presentation orders, however, was the 'need' for participants to reprocess the input. This could imply that, although the strength of the conflict might not have been influenced, the presentation order may have affected the threshold for reprocessing to occur.

Brain mechanism involved in conflict monitoring

The second main issue that was investigated in this thesis, concerned the brain mechanism involved in conflict monitoring in visual language perception. In particular we focused on the posterior part of the left inferior frontal gyrus (lIFG), encompassing Brodmann's area (BA) 44 and 45 (Broca's area). Broca's area has been implicated in sentence processing. Specifically, a connection with syntactic processing has often been made since patients with Broca's aphasia show agrammatic production and have difficulties in understanding syntactically complex sentences (e.g., Goodglass & Berko, 1960; Grodzinsky, 2000). However, a lesion to Broca's area does not necessarily lead to Broca's aphasia (Dronkers et al., 2004). Furthermore, the lIFG has also been implicated in cognitive control tasks that do not require syntactic or language-specific processing. For instance, in the Stroop task healthy participants show increased lIFG activation for incongruent trials in which a prepotent response must be overridden. These findings suggest that the lIFG is more generally involved in cognitive control processes. To unify these findings of lIFG functioning reported in the cognitive control literature with findings from the psycholinguistic literature, Novick et al. (2005) proposed that the lIFG plays an important role in resolving representational conflicts more generally, and these conflicts need not be syntactic in nature. When a conflict between competing representations is present, the lIFG is proposed to adjust control to bias one of the representations, for instance the ink colour in case of the Stroop task. Accordingly, in syntactically ambiguous garden-path sentences – which have also been shown to increase lIFG activation – the lIFG is thought to override the automatic dominant parse and recover the dispreferred parse, thereby preventing misinterpretations. In support of this proposal of a general conflict resolution mechanism in lIFG, January et al. (2009) reported similar lIFG activation within the same participants for representational conflicts elicited by incongruent trials in the Stroop task and syntactically ambiguous sentences.

In the fMRI studies described in Chapter 4 and 5 we further investigated this proposal of a general conflict resolution mechanism in lIFG with respect to errors in visual language perception. According to the monitoring theory of language perception, errors in language perception can create a conflict between an expected and an observed linguistic element, thereby signalling that adjustments in control are needed. Therefore, the question for the fMRI study of Chapter 4 was whether these representational conflicts, elicited by different types of language errors, would elicit co-localized lIFG activation. Such a finding would support the proposal of the lIFG as a general conflict resolution area. To this end, the lIFG activation elicited by syntactic agreement violations (e.g., 'The clean clothes and towels hangs…') and spelling errors (e.g., ''The pillows are stuffed with feathurs...') was compared within the same group of participants. Regions of interest (ROIs) – including the lIFG – were defined based on two meta-analyses. The results from the ROI analysis indicated that syntactic agreement violations and spellings violations elicited increased activation in the lIFG compared to their correct controls. Hence, these results extended the proposal that the lIFG is involved in implementing cognitive control to resolve representational conflicts, to the processing of errors in visual language perception. Additionally, the co-localized lIFG activation to syntactic agreement violations and spelling errors was in line with the proposal, as suggested by Novick et al. (2005), that these representational conflicts need not be syntactic in nature.

Additionally, in the fMRI study of Chapter 5 we investigated whether – as January et al. (2009) had reported for syntactically ambiguous sentences – conflict resolution in the Stroop task would generalize to conflict resolution for errors in language perception. To this end, participants read sentences that contained syntactic agreement violations (e.g., 'The clean clothes and towels hangs…') and violations of plausibility (e.g., 'The eye consisting of among other things a pupil, iris and eyebrow/sticker…'). In addition they performed a Stroop task, to localize the part within the lIFG (BA 44/45) that showed increased activation to incongruent trials. In line with January et al. (2009), we determined this part of the lIFG for each participant individually, and examined its sensitivity to representational conflicts arising from syntactic agreement and plausibility violations. Based on the proposal that the lIFG is involved in implementing cognitive control to resolve representational conflicts of different types, we predicted that both syntactic agreement violations and plausibility violations should elicit increased activation in the same lIFG area as determined from the Stroop task. The results from the ROI analysis indeed supported this prediction: both syntactic and plausibility violations showed co-localized lIFG activation with the incongruent trials of the Stroop task. These findings again further strengthened the proposal by Novick et al. (2005) that the lIFG is engaged in the resolution of various types of representational conflicts.

The role of the anterior cingulate cortex in conflict monitoring

In describing the brain mechanism involved in conflict monitoring we have focused on the lIFG. As discussed in the introduction, however, in the action domain generally two brain regions are thought to play an important role in conflict monitoring. The prefrontal cortex (PFC), for which we have focussed on the lIFG, is one of these regions. The PFC is thought to implement cognitive control by biasing neural activity in other brain areas which can guide the task-relevant neural pathways in a goal-directed manner (e.g., Miller, 2000; Miller & Cohen, 2001). For instance, as discussed in Chapter 4, the increased activation in the left inferior temporal/fusiform gyrus for misspelled words could point towards (re)processing of the visual wordform, since this area closely corresponds to the visual word form area (VWFA). The VWFA is thought to compute structural representations of words from abstract letter representations (e.g., Dehaene et al., 2002). In Chapter 5, a similar region also shows increased activation for degraded words, which might point to the fact that this process of computing structural representations is more difficult for degraded than undegraded words.

However, a second brain region that is thought to play an important role in conflict monitoring in the action domain is the anterior cingulate cortex (ACC). The ACC has been implicated in the detection of conflicts between competing responses, thereby signalling to the PFC that control adjustments are needed (e.g., Cohen et al., 2000; Miller & Cohen, 2001). In the fMRI studies of Chapter 4 and 5 in this thesis, we did not consistently find ACC activation for representational conflicts elicited by various types of language errors. Only in Chapter 4 an increased activation was found for misspelled words in the ACC ROI when compared to correctly spelled words. This ACC ROI, however, was primarily localized in BA 6, while monitoring for response conflict is often reported to involve more of BA 24 and 32 – though the activation often spreads to BA 6 and 8 (Botvinick, Cohen, & Carter, 2004; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). It could be that we did not consistently find increased ACC activation for conflicts elicited by language errors, because these conflicts did not occur at the level of response selection. The finding of increased ACC activation in the action domain has been firmly established for tasks in which there is competition between multiple responses, for instance in the incongruent trials of the Flanker task (e.g., →→←→→: the participant needs to respond to the central arrow and press the left button, while the surrounding arrows point to the right). These tasks require prepotent responses (e.g., pressing the right button) to be overridden. However, for the language errors studied in the present thesis no responses were required. Therefore, no overriding of a prepotent *response* was needed, but instead an expected *representation* needed to be overridden. In line with this explanation, it has been proposed in several studies that while the ACC is primarily responsible for detecting conflict at the level of response selection, the PFC is more involved in dealing with conflicts at non-response levels (e.g., Milham et al., 2003; Milham et al., 2001; Nelson, Reuter-Lorenz, Sylvester, Jonides, & Smith, 2003). However, it has also been indicated that the ACC function generalizes beyond conflict monitoring at the response level to a broader monitoring function, since some studies do find ACC activation to conflicts at other levels of processing (e.g., Badre & Wagner, 2004; Botvinick et al., 2004). Hence, it is a task for future studies to further address the involvement of the ACC in conflict monitoring at other processing levels besides the response-based level, to establish to what extent the area can be found to be consistently activated by conflicts at non-response levels.

Monitoring response to a lack of bottom-up information

The last main issue that was addressed in the present thesis concerned the question of whether, besides representational conflicts, other problems in language perception like a lack of bottom-up information might also elicit a monitoring response. The idea behind this question was that not only representational conflicts can hamper our understanding and require adjustments in attentional control. Words that are difficult to read also disrupt comprehension, and they might signal that extra attention is needed as well. To examine this, we constructed a visual degradation condition. This condition consisted of the weakly predictive sentences from Chapter 4 (e.g., 'At that spot there sometimes lie <u>feathers</u>...') which did not elicit an expectation for a certain word, and the critical words that were used did not contain an error of any kind. Therefore, no representational conflict between an expected and an observed linguistic element was assumed to be present. However, what we now manipulated was the readability of the critical word: it could either be presented normally at full vision, or it was degraded by randomly removing 75% of the pixels.

In Chapter 5, this visual degradation condition was investigated in an fMRI study. To this end, in the fMRI study that was described previously we added a visual degradation condition, next to the errors in language perception (i.e., syntactic agreement and plausibility violations) and the Stroop task. If, as the language errors had shown, this visual degradation condition would yield increased activation in the lIFG region that was based on the Stroop task, this could indicate that the lIFG implements control to compensate for a lack of bottom-up information as well. The results indeed showed increased lIFG activation for all conditions. We concluded that this could indicate that – next to implementing control to resolve representational conflicts by overriding a prepotent or expected representation – the area is also important when a biasing of attention is needed to compensate for a lack of bottom-up information in visual language perception. We proposed that these findings could indicate that the lIFG is more generally involved in implementing cognitive control when language comprehension is hampered, and related the findings to the meta-analysis by Duncan and Owen (2000). Duncan and Owen (2000) found that very much the same regions in the frontal lobe (including lIFG and ACC) are recruited for various types of cognitively demanding tasks, which require more mental effort and hence more attentional control. Similarly, for the ACC specifically, Botvinick et al. (2004) have also suggested a more general outcome monitoring function, of which conflict monitoring might just be one example. They propose that in its evaluative role, conflicts may just be one of the signals to which the ACC is sensitive, and these conflicts may serve as an index of the demand for mental effort. The area might therefore be activated not only in the case of conflicts, but more generally when a task is cognitively difficult. These proposals, however, are still speculative and further research is needed to investigate the extent of this possibility. However, such a proposal might explain why, in the case of language comprehension, next to representational conflicts, degraded words also show increased activation in the lIFG: both situations create a state of indecision in the language system and require extra mental effort to be resolved successfully.

As discussed in Chapter 5, however, for the visual degradation condition we cannot completely exclude the possibility of the presence of another type of conflict, namely 'underdetermined response conflict', which has also been shown to increase activation in the lIFG. This type of conflict arises when multiple weakly activated representations or responses compete to be selected, as in the case of the category fluency task (e.g., name as many exemplars from the category 'fruits'). Similarly, it could be that degraded words, since they are difficult to read, give rise to several weakly activated representations. However, we argued that if such a conflict is present in our visual degradation condition, the type of control adjustments that are needed to compensate for the lack of bottom-up information would differ from the other representational conflict conditions that we studied. In the case of syntactic agreement violations, plausibility violations and the Stroop task, control adjustments are proposed to involve the strengthening of the unexpected/non-prepotent representation. For the visual degradation condition, however, all representations are equally expected/prepotent, and it is therefore unclear which representation should be strengthened.

In Chapter 6, the visual degradation condition was examined in an ERP study. Participants' ERP response to visual degradation was compared with the ERP response to two types of representational conflict (i.e., syntactic agreement and plausibility violations). We hypothesized that, if the language user deals with these two types of situations in a similar way, the visual degradation condition should elicit a positivity in the P600 window just as what has been previously found for representational conflicts. The results indicated a long-lasting positivity for the visual degradation condition between 300-800 msec with a central-posterior scalp distribution. This time window encompasses the window in which the P600 effect is typically observed (i.e., 500-800 msec), and the central-posterior scalp distribution is also in line with the general P600 topography. However, within the same participants, the positivity that was found in response to degraded words did show some variations in timing and distribution across the scalp compared to the positivities that were found for the syntactic agreement violations (550-800 msec, broad scalp distribution) and the deeply implausible sentence continuations (700-1000 msec, mainly left central-posterior scalp distribution). We proposed that a general monitoring process could underlie these positivities. Both representational conflicts and a lack of bottom-up information interrupt language comprehension and bring the system into a state of indecision. Thereby, they signal that control adjustments are needed to check for possible processing errors or to identify the stimulus. The fact that these positivities show some variation in their timing and scalp distribution might be related to the type and complexity of the information that interrupts comprehension and that needs to be reprocessed or identified.

A family of positivities?

In Chapter 2, 3 and 4 we argued that strong conflicts between an expected and an observed linguistic element can bring the language system into a state of indecision, thereby triggering reprocessing of the input to check for possible processing errors. In line with the monitoring theory of language perception this monitoring process, in which a representational conflict signals reprocessing, is thought to elicit a P600 effect in the EEG. The finding of an increased positivity to visually degraded words in Chapter 6, was taken to indicate that the monitoring theory of language perception should be extended. Besides strong expectancy violations, a lack of bottom-up information may also signal that extra processing is needed. More generally, we proposed that a general monitoring process could underlie the various positivities that we found, which – depending on the type and complexity of the information – could show some variations in their timing and scalp distribution.

This proposal implies that we might more generally speak of a 'family of positivities'. What the members of this family could have in common is that they signal problems for language comprehension, which require extra attention to be resolved. However, the question arises which members actually belong to this family – that is, how far should this family be extended? As discussed in Chapter 2, P600-like positivities have also been found outside of the language domain, for instance, in the case of musical and arithmetic violations. Furthermore, in Chapter 3 and 6 we proposed that oddball stimuli, which elicit a P3b, could also belong to the same family of positivities. Additionally, as discussed in Chapter 6, visually degraded stimuli elicit increased amplitudes of late positivities in various non-linguistic tasks. As discussed in Chapter 6, and in line with our interpretation of the fMRI results in Chapter 5, what all these situations might have in common is that they are more 'cognitively demanding', thereby requiring more attentional control or mental effort. However, again it must be noted that this proposal is speculative and in need of further research. For instance, what stimuli or tasks would satisfy to be 'cognitively demanding', and which would not? Should all these stimuli or tasks involve some kind of expectancy violation or a lack of bottom-up information, or are there other 'cognitively demanding' inputs to distinguish? With the data at hand we are unable to answer these questions conclusively. However, at least the positivities in the present thesis are taken to indicate that in visual language perception, strong representational conflicts as well as a lack of bottom-up information can create a state of indecision for the language system, thereby signalling that reprocessing or extra processing of the input is needed.

Future challenges

Relating EEG and fMRI findings

In the present thesis we conducted both EEG and fMRI studies to investigate monitoring in visual language perception. While EEG has a high temporal resolution and a low spatial resolution, fMRI has a high spatial resolution and a low temporal resolution. These methods can therefore be used to complement each other. However, at present it is still poorly understood how the electrophysiological and hemodynamic response are related to each other. It is therefore hard to answer the question how our findings in the EEG and fMRI can be related.

For instance, as discussed in Chapter 4, conflict strength affected the P600 amplitude to spelling violations in the EEG study, but it did not affect the hemodynamic response in the fMRI study. We put forward that these different findings could be due to a difference in temporal sensitivity of both measurements: while ERP measurements are time-locked to the critical word, fMRI measurements also reflect additional processes occurring after the critical word which might have resulted in a null finding. In addition, we speculated that, if this would not be a null finding, then it could implicate that while the P600 amplitude could be (partly) related to conflict strength, the activations in the fMRI might reflect the (guidance of the) reprocessing. Furthermore, in Chapter 6 we speculated about how our interpretation of the ERP patterns found in Chapter 3 and 5 to mildly (N400) and deeply implausible sentences (N400-P600), could be related to the finding of increased lIFG activation for mildly compared to deeply implausible sentences. We suggested that both conditions might require different kinds of control adjustments. On the one hand, in the deeply implausible condition integration efforts might cease quickly and control adjustments may be needed for reprocessing. On the other hand, in the mildly implausible condition control adjustments might be needed to integrate the unexpected information. The latter case might require longer maintenance of the unexpected information, and more or longer attentional enhancement, hence stronger lIFG activation.

It must be noted that the abovementioned suggestions are speculative, and it remains an open question *whether* and, if so, *how* our EEG and fMRI findings can be related exactly. Maybe future studies that simultaneously acquire EEG and fMRI measurements will enhance our understanding on this issue, though this type of measurement first has its own obstacles to overcome. What we do assume, however, is that both the P600 effects we find in our EEG studies and the increased lIFG activation that we report in our fMRI studies are reflections of an underlying monitoring process which evaluates the demands for control.

Monitoring across modalities

In the present thesis we investigated monitoring in visual language perception. In the experiments that we conducted, the participants read sentences, in which we had embedded various types of anomalies. These sentences were presented word-by-word on a computer screen. Visual presentation is often used in language research, because visual stimuli are easier to present and manipulate in a controlled fashion. Spoken language, however, is probably used more widely to communicate than written language. In addition, presenting continuous speech is more natural than the word-by-word presentation often used in visual language comprehension studies. Therefore, it would also be interesting to examine monitoring in the auditory modality, to see whether the way that the language user deals with comprehension problems arising in the visual modality could be generalized to how they deal with comprehension problems in the 'more natural' auditory modality (e.g., 'mishearings'). Previous EEG studies already investigated syntactic violations and ambiguities in the auditory modality by presenting participants with spoken sentences. In general, similar P600 effects were found in the visual and auditory modality (e.g., Friederici et al., 1993; Hagoort & Brown, 2000; Osterhout & Holcomb, 1993). Similarly, various fMRI studies have investigated the comprehension of spoken language by embedding different kinds of anomalies in spoken sentences (e.g., Cooke et al., 2006; Friederici et al., 2003; Kuperberg et al., 2000; Wartenburger et al., 2004). These studies show activation in large networks of brain areas, of which some of course include areas involved in auditory processing, but activation in the lIFG is also often reported. A systematic investigation of, for instance degraded words in sentences and different types of representational conflicts (e.g., syntactic and plausibility violations, Stroop task) within the same participants, using a similar experimental design and task in both the visual and auditory modality, could give an indication whether, and if so, to what extent, the monitoring processes are shared across modalities.

Conclusion

In the studies described in the present thesis I further investigated monitoring in visual language perception. First, I have shown that the strength of a conflict between an expected and an observed linguistic element can influence the monitoring process, as reflected by differences in the P600 effect. Second, I have demonstrated that an important cognitive control area in the brain – the lIFG – is involved in this monitoring process for various types of language errors, thereby connecting to the proposal of the lIFG as a general conflict resolution area. Third, I have shown that, not only representational conflicts, but also a lack of bottom-up information in visual language perception can elicit a monitoring response, as reflected by a positivity in the EEG and increased lIFG activation. Taken together, the studies presented in this thesis strengthen the role of the cognitive control process of monitoring in visual language perception. To better understand how the language system deals with states of indecision, it is important to realize that language processes are not isolated processes but that they are in continuous interaction with other cognitive processes.

Appendices

APPENDIX 1: EXPERIMENTAL MATERIALS CHAPTER 3

Plausibility condition (plausible/mildly implausible/deeply implausible)

1. VASTE LASTEN ZOALS GAS, WATER EN LICHT/VERWARMING/ROOKWORST MOETEN OOK BETAALD WORDEN.
2. ALLE DELEN VAN HET GEZICHT ZOALS DE OREN, NEUS EN MOND/SPROETEN/BAL VERSCHILLEN PER PERSOON.
3. LICHAAMSDELEN ZOALS EEN ARM, NEK EN TEEN/HAAR/TELESCOOP HEBBEN ELK HUN EIGEN FUNCTIE.
4. EMOTIES ZOALS VREUGDE, VERDRIET EN ANGST/LACH/TOREN ZORGEN OOK VOOR LICHAMELIJKE VERANDERINGEN.
5. HET ROKEN VAN EEN SIGAAR, PIJP EN SIGARET/DRUGS/KAPSTOK IS VERSLAVEND.
6. HUISDIEREN ZOALS KONIJNEN, HONDEN EN KATTEN/ZWIJNEN/PLAKBAND MOETEN GOED VERZORGD WORDEN.
7. DE SEIZOENEN ZOALS ZOMER, HERFST EN WINTER/VOORJAAR/KLAPPER WISSELEN ELKAAR AF.
8. DAT SERVIES BESTAANDE UIT ONDER ANDERE GLAZEN, KOMMEN EN BORDEN/PANNEN/TRAPPEN IS TWAALFDELIG.
9. BIJBELSE FIGUREN ZOALS JOZEF, MARIA EN JEZUS/KAÏN/ETIKET ZIJN OP VELE AFBEELDINGEN TE ZIEN.
10. VOOR HET OPENBAAR VERVOER ZOALS METRO, TRAM EN BUS/TAXI/GRENS MOET JE EEN KAARTJE KOPEN.
11. ZUIVELPRODUCTEN ZOALS YOGHURT, KAAS EN MELK/EI/BAK VIND JE IN DE KOELING.
12. MEUBELS WAARONDER EEN BANK, BED EN KAST/LAMP/RADAT VIND JE IN DE WOONWINKEL.
13. DIE BEELDEN VAN KLEI, BRONS EN KOPER/ZAND/LOGO STAAN TENTOONGESTELD IN HET MUSEUM.
14. TALEN OP DE MIDDELBARE SCHOOL ZOALS NEDERLANDS, DUITS EN FRANS/FRIES/CADEAU ZIJN ERG VEELZIJDIG.
15. GEESTELIJKEN ZOALS PRIESTERS, DOMINEES EN PASTOORS/DEKENS/POTTEN WIJDEN ZICH AAN HUN RELIGIE.
16. MUZIEK OP ONDER ANDERE CASSETTEBANDJES, CD'S EN PLATEN/RADIO/LUCHTKUSSENS GEEFT SFEER AAN EEN FEEST.
17. BEKENDE HOOFDSTEDEN ZOALS AMSTERDAM, PARIJS EN ROME/ZWOLLE/BRIEVENBUS HEBBEN VEEL INWONERS.
18. VERSCHEIDENE RELIGIES ZOALS HINDOEÏSME, ISLAM EN CHRISTENDOM/KATHOLIEK/GRONDWET KUNNEN MET ELKAAR VERGELEKEN WORDEN.
19. DIEREN OP DIE BOERDERIJ ZOALS KIPPEN, VARKENS EN KOEIEN/CAVIA’S/KUILEN HEBBEN GEEN RUIMTE OM TE SCHARRELEN.
20. KLEDING ZOALS TRUIEN, BROEKEN EN ROKKEN/HOEDEN/SLUIZEN LIGT IN DE KLERENKAST.
21. WAPENS ZOALS EEN ZWAARD, MES EN PISTOOL/BOOG/VUILNISZAK ZIJN BEDOELD OM ANDEREN TE VERWONDEN.
22. DIE CAMPING MET ONDER ANDERE CAMPERS, CARAVANS EN TENTEN/ZWEMBAD/GROTTEN IS AL HELEMAAL VOL.
23. BADKAMERS MET ONDER ANDERE EEN DOUCHE, TOILET EN BAD/BIDET/MEMO VIND JE IN DIT HOTEL.
24. ONGEDIERTE ZOALS MUIZEN, KAKKERLAKKEN EN RATTEN/SLANGEN/FOLIE MOET METEEN BESTREDEN WORDEN.
25. INGREDIËNTEN VOOR EEN APPELTAART ZOALS BLOEM, ROZIJNEN EN BOTER/SLAGROOM/STREEP KOOPT HIJ IN DE SUPERMARKT.
26. CIRCUSDIEREN ZOALS TIJGERS, OLIFANTEN EN LEEUWEN/ZEBRA’S/STIFTEN MOETEN GOED VERZORGD WORDEN.
27. BEROEPEN IN DE FILMWERELD ZOALS PRODUCENT, REGISSEUR EN ACTEUR/MODEL/BIEB WORDEN VAAK GOED BETAALD.
28. OPPERVLAKTEWATER ZOALS EEN SLOOT, RIVIER EN BEEK/WATERVAL/LETTER KAN VERVUILD WORDEN.
29. SPEELKAARTEN WAARONDER SCHOPPEN, HARTEN EN RUITEN/KONINGIN/SCHUTTING GEBRUIK JE BIJ BRIDGEN.
30. TIJDENS MAALTIJDEN ZOALS ONTBIJT, AVONDETEN EN LUNCH/DESSERT/BOODSCHAP NEEMT MEN VOEDSEL TOT ZICH.
31. PLANETEN ZOALS SATURNUS, MARS EN VENUS/ZON/NUMMER ZIJN NAGENOEG ROND.
32. GEDURENDE LEVENSFASEN VAN DE MENS ZOALS BABY, PEUTER EN KLEUTER/KINDERTIJD/GEDRAG VINDT ONTWIKKELING PLAATS.
33. ORGANEN ZOALS HART, LONGEN EN NIEREN/KLIEREN/KACHEL KUNNEN OOK WORDEN AANGETAST.
34. VOORSTELLINGEN IN DE SCHOUWBURG ZOALS CABARET, TONEELSTUK EN OPERA/ORKESTEN/DOCENT ZIJN SNEL UITVERKOCHT.
35. VERSCHILLENDE LANDEN IN EUROPA ZOALS BELGIË, DUITSLAND EN GRIEKENLAND/TURKIJE/DIPLOMA HEBBEN EEN GOEDE ONDERLINGE VERSTANDHOUDING.
36. ZIJN WERKDAGEN WAARONDER MAANDAG, DINSDAG EN WOENSDAG/ZONDAG/ROLSTOEL GAAN SNEL VOORBIJ.
37. PROVINCIES ZOALS DRENTHE, LIMBURG EN ZEELAND/VLAANDEREN/PAAL VORMEN DE BESTUURSLAAG TUSSEN HET RIJK EN DE GEMEENTEN.

38. BRANDSTOFFEN VOOR EEN AUTO ZOALS DIESEL, GAS EN BENZINE/WATERSTOF/NERF WORDEN STEEDS DUURDER.
39. CONTINENTEN ZOALS AFRIKA, EUROPA EN AZIË/NOORDPOOL/MARKTKRAAM VERPLAATSEN ZICH VOORTDUREND.
40. VERF IN ALLERLEI KLEUREN WAARONDER ROOD, WIT EN BLAUW/PASTEL/POOT GEBRUIKT HIJ VOOR HET SCHILDEREN.
41. DE JACHT OP ONDER ANDERE EVERZWIJNEN, KONIJNEN EN VOSSEN/OSSEN/VUURWERK IS WEER GEOPEND.
42. DEZE UITRUSTING VOOR DE WINTERSPORT MET EEN SKIBRIL, JAS EN MUTS/ZONNEBRAND/KLOOSTER ZIET ER MOOI UIT.
43. SCHOENEN ZOALS PUMPS, LAARZEN EN SANDALEN/SCHAATSEN/VAZEN ZIJN ER IN ALLERLEI MERKEN.
44. EEN ENGELS ONTBIJT MET WORSTJES, EIEREN EN SPEK/BROOD/BRADERIE GAAT ER WEL IN.
45. DELEN VAN EEN HAND ZOALS EEN DUIM, WIJSVINGER EN PINK/BOT/TOETS ZIJN ONDERLING VERBONDEN.
46. BEKENDE WETENSCHAPPERS ZOALS EINSTEIN, NEWTON EN DARWIN/POPPER/MAP WAREN ERG VINDINGRIJK.
47. KRUIDEN ZOALS BIESLOOK, BASILICUM EN TIJM/MOSTERD/RAPPORT WORDEN VEEL GEBRUIKT TIJDENS HET KOKEN.
48. VISSEN ZOALS DE SNOEK, BAARS EN PALING/HAAI/VLAG LEVEN IN WATER.
49. NOTEN ZOALS EEN PINDA, HAZELNOOT EN AMANDEL/KOKOSNOOT/PLEIN KUNNEN EEN ALLERGISCHE REACTIE VEROORZAKEN.
50. DE VERTREKKEN IN DAT HUIS ZOALS DE WOONKAMER, SLAAPKAMER EN EETKAMER/GANG/WIELDOP HEBBEN EEN EIGEN STIJL.
51. EEN RIDDERUITRUSTING BESTAANDE UIT ONDER ANDERE EEN HARNAS, SCHILD EN LANS/PAARD/GELUID STAAT TENTOONGESTELD.
52. SCHOENEN BESTAANDE UIT ONDER ANDERE ZOLEN, HAKKEN EN VETERS/LIP/TEST BESCHERMEN JE VOETEN.
53. HET VLEES VAN DE SLAGER ZOALS GEHAKT, SAUCIJZEN EN BIEFSTUK/TONG/BALKON LIGT IN DE VITRINE.
54. DRUGS ZOALS COCAÏNE, MARIHUANA EN HASJ/ALCOHOL/LUCHT HEBBEN EEN DROGERENDE WERKING.
55. ZEEDIEREN ZOALS GARNALEN, INKTVIS EN KREEFT/ANEMOON/VLIEGER WORDEN IN DIT RESTAURANT VERS BEREID.
56. AAN WOONRUIMTEN ZOALS EEN HUIS, FLAT EN BUNGALOW/IGLO/MONITOR IS SOMS EEN TEKORT.
57. KONINKLIJKE LIEDEN ALS BEATRIX, WILLEM-ALEXANDER EN CLAUS/CHARLES/KALKOEN GAAN SOMS OP STAATSBEZOEK.
58. GROENTEN ZOALS SLA, TOMATEN EN KOMKOMMER/AARDAPPELS/WOESTIJN KOOP JE BIJ DE GROENTEMAN.
59. BOMEN ZOALS EEN SPAR, EIK EN BERK/PALM/SCHETSBOEK STAAN IN HET BOS DOOR ELKAAR HEEN.
60. SOORTEN WEERTYPEN ZOALS REGEN, ZON EN HAGEL/ORKAAN/POSTER WORDEN VOORSPELD.
61. INSECTEN ZOALS KEVERS, MUGGEN EN WESPEN/LARVEN/STROPDASSEN LEVEN IN HET NATUURGEBIED.
62. ZWEMKLEDING ZOALS EEN BADPAK, ZWEMBROEK EN BIKINI/FLIPPER/SNELWEG HEEFT VELE KLEUREN.
63. ONDERGOED ZOALS EEN BEHA, BOXERSHORT EN SLIP/PANTY/PARKET DRAAG JE ONDER JE KLEREN.
64. TOETJES ZOALS VLA, YOGHURT EN PUDDING/KOFFIE/BEHANG NEEM JE AAN HET EINDE VAN DE MAALTIJD.
65. HET OOG BESTAANDE UIT ONDER ANDERE EEN PUPIL, IRIS EN NETVLIES/WENKBRAUW/STICKER IS ERG GEVOELIG.
66. GRAANSOORTEN ZOALS HAVER, GERST EN ROGGE/GIST/PLANK WORDEN VERBOUWD OP HET LAND.
67. OOK VOGELS ZOALS DE EKSTER, KRAAI EN SPREEUW/KAKETOE/STANDAARD HEBBEN TIJDENS WARM WEER VEEL VOCHT NODIG.
68. PSYCHISCHE STOORNISSEN ZOALS DEMENTIE, SCHIZOFRENIE EN AUTISME/AFASIE/DOP KOMEN VAAK VOOR.
69. EENHEDEN ZOALS LITER, METER EN KILOGRAM/HOOGTE/BRIGADE ZIJN GEMAKKELIJK OM INTERNATIONAAL GEGEVENS UIT TE WISSELEN.
70. IN MIJNEN MET BIJVOORBEELD KOLEN, GOUD EN ERTS/STENEN/KNOPPEN WORDT HARD GEWERKT.
71. VERSCHILLENDE ARTSEN ZOALS EEN CARDIOLOOG, DERMATOLOOG EN NEUROLOOG/THERAPEUT/WANDELING WERKEN IN EEN ZIEKENHUIS.
72. SNOEPJES ZOALS LOLLIES, ZUURTJES EN DROP/KOEKJES/RIJLES ZITTEN IN DE TROMMEL OM UIT TE DELEN.
73. CHEMISCHE ELEMENTEN ZOALS NATRIUM, KALIUM EN CALCIUM/PLASTIC/BEL WORDEN DOOR SCHEIKUNDIGEN GEBRUIKT.
74. ETEN BIJ DE SNACKBAR ZOALS EEN FRIETJE, KROKET EN HAMBURGER/SALADE/ENVELOP VULT DE MAAG.
75. SCHEPEN ZOALS SLEEPBOTEN, VEERBOTEN EN DUIKBOTEN/KANO'S/RECEPTIES HEBBEN EEN BEMANNING NODIG.
76. SIERADEN ZOALS HORLOGES, KETTINGEN EN OORBELLEN/KRALEN/WONDEN WORDEN VEEL GEDRAGEN.
77. TENNISSLAGEN ZOALS DE FOREHAND, BACKHAND EN SERVICE/LOB/PILAAR WISSELEN ELKAAR IN EEN WEDSTRIJD AF.
78. DIE ELEKTRONICAZAAK MET COMPUTERS, TELEVISIES EN EN PRINTERS/KOELBOXEN/FLESSEN DRAAIT VEEL WINST.
79. DIE SPEELTUIN MET ONDER ANDERE EEN KLIMREK, SCHOMMEL EN ZANDBAK/PRULLENBAK/KAART WORDT DRUK BEZOCHT.
80. VOETBALTERMEN ZOALS HOEKSCHOP, BUITENSPEL EN STRAFSCHOP/DOEL/BLOEMPOT GEBRUIKT DE VERSLAGGEVER TIJDENS DE WEDSTRIJD.

81. ARTIKELEN BIJ DE DROGIST ZOALS PARFUM, CRÈME EN SHAMPOO/VOEDING/BIDON STAAN UITGESTALD OP DE SCHAPPEN.
82. BOTTEN VAN EEN SKELET ZOALS BORSTBEEN, SLEUTELBEEN EN SCHEENBEEN/POLS/KOOI BEVATTEN WEEFSEL.
83. VERSCHILLENDE MENUGANGEN ZOALS VOORGERECHT, HOOFDGERECHT EN NAGERECHT/SOEP/PUNAISE STAAN OP DE KAART.
84. VERSCHILLENDE SOORTEN GLAZEN ZOALS WIJNGLAZEN, THEEGLAZEN EN BIERGLAZEN/BEKERS/STOPCONTACT STAAN OP EEN RIJ.
85. TUINGEREEDSCHAP ZOALS EEN HARK, GRASMAAIER EN SNOEISCHAAR/BIJL/VERDIEPING WORDT GEBRUIKT OM DE TUIN TE ONDERHOUDEN.
86. VERSCHILLENDE SOORTEN BEDDEN ZOALS EEN TWEEPERSOONSBED, TWIJFELAAR EN STAPELBED/WIEG/KROON STAAN IN DIE SHOWROOM.
87. DIEREN IN DE DIERENTUIN ZOALS TIJGERS, APEN EN GIRAFFEN/VLINDERS/TOVERSTAF LEVEN BINNEN OMHEININGEN.
88. VOOR ZIEKTES ZOALS AIDS, MALARIA EN LEPRA/GRIEP/SNOER PROBEERT MEN GOEDE MEDICIJNEN TE ONTWIKKELEN.
89. PRODUCTEN VOOR JE HAAR ZOALS HAARLAK, MOUSSE EN GEL/BORSTEL/KLOK STAAN IN HET LAATSTE GANGPAD.
90. ELKE MENSELIJKE ZANGSTEM ZOALS BAS, TENOR EN SOPRAAN/VROUWENSTEM/KORF HEEFT EEN BEPAALD BEREIK.
91. DIE BAND BESTAANDE UIT EEN ZANGER, DRUMMER EN GITARIST/VIOLIST/LOEP MAAKT MOOIE MUZIEK.
92. ARTIKELEN IN DE KRANT ZOALS NIEUWSBERICHTEN, INTERVIEWS EN COLUMNS/HOROSCOOP/RIJBEWIJS ZIJN ER OM TE LEZEN.
93. MIDDELEN OM SCHOON TE MAKEN ZOALS ZEEP, SCHUURMIDDEL EN BLEEK/DWEIL/PLINT RUIKEN MEESTAL LEKKER FRIS.
94. ZWEMTECHNIEKEN ZOALS WATERTRAPPELEN, SCHOOLSLAG EN VLINDERSLAG/DUIK/REGIO LEERT HIJ BIJ ZWEMLES.
95. ATTRACTIES OP DE KERMIS ZOALS DRAAIMOLEN, BOTSAUTO'S EN REUZENRAD/SUIKERSPIN/FAMILIE ZIJN MOOI VERSIERD.
96. DIEREN IN POOLGEBIEDEN ZOALS IJSBEREN, ZEEHONDEN EN PINGUÏNS/PLANKTON/TOUW HEBBEN ZICH AANGEPAST AAN HET KOUDE KLIMAAT.
97. INSTRUMENTEN ZOALS TROMPET, KLARINET EN SAXOFOON/BARITON/KNOOP WORDEN VEEL BESPEELD.
98. FRISDRANKEN ZOALS COLA, SINAS EN CASSIS/RANJA/HEL WORDEN VEEL GEDRONKEN.
99. RAAMBEKLEDING ZOALS LUXAFLEX, GORDIJNEN EN LAMELLEN/HORREN/SCRIPTIE IS IN VELE MATERIALEN VERKRIJGBAAR.

APPENDIX 2: EXPERIMENTAL MATERIALS CHAPTER 4

Spelling condition (correctly spelled/misspelled)

For each sentence pair the first sentence is the high-cloze probability sentence, and the second sentence is the low-cloze probability sentence.

1. DIE BRUG VOOR FIETSERS STEUNT OP PILAREN/PILARUN VAN BETON.
   DIE PERSOON WEET HEEL VEEL OVER PILAREN/PILARUN VAN TEMPELS.
2. OP HET STRAND BOUWEN DE JONGENS EEN KASTEEL VAN ZAND/ZANT WAAR ZE ERG TROTS OP ZIJN.
   VOOR HUN PLEZIER ZIJN DIE MENSEN DRUK BEZIG MET ZAND/ZANT EN MAKEN ER EEN SCULPTUUR VAN.
3. DAT TOPMODEL WEEGT MINDER DAN VIJFTIG KILO/KIELO DOORDAT ZE ALTIJD LIJNT.
   IN DIE PLASTIC ZAK ZIT EEN KILO/KIELO VIS VOOR HET AVONDETEN.
4. DEZE TWAALFJARIGE CELLIST HEEFT ERG VEEL TALENT/TALEND EN REIST HEEL EUROPA DOOR.
   ZIJ ZIJN VAN MENING DAT HET TALENT/TALEND VAN DEZE GROEP MATIG IS.
5. DIE OPLETTENDE WINKELIER BESCHULDIGT DE JONGENS VAN DIEFSTAL/DIEFSDAL EN SCHELDT HEN UIT.
   ZIJ VERBAAST ZICH NOG STEEDS OVER DE DIEFSTAL/DIEFSDAL DIE OVERDAG PLAATSVOND.
6. IN DIE DISCO DRAAIT DE DJ ERG GOEDE MUZIEK/MUSIEK WAAR IEDEREEN VAN HOUDT.
   DIE SCHRIJFSTER WERKT AAN EEN VERHAAL OVER MUZIEK/MUSIEK DIE DE MENSEN HYPONOTISEERT.
7. DIE INTERNATIONALE JOURNALIST SPREEKT MEERDERE VREEMDE TALEN/TALUN WAARONDER FRANS EN SPAANS.
   ZIJ VINDEN HET LEUK OM ALLERLEI TALEN/TALUN MET ELKAAR TE SPREKEN.
8. IN DIE BIBLIOTHEEK LENEN SCHOLIEREN BOEKEN/BOEKUN OM MEE NAAR HUIS TE NEMEN.
   HET INTERESSEERT HEM NIET DAT DE BOEKEN/BOEKUN UIT ELKAAR VALLEN DOOR HET GEBRUIK.
9. DE PROJECTONTWIKKELAARS HALEN OPDRACHTEN BINNEN DOOR HUN VLOTTE BABBELS/BABBULS DIE HEN NOG GOED VAN PAS ZULLEN KOMEN.
   VOLGENS HET NEDERLANDSE WOORDENBOEK KUN JE OOK OVER BABBELS/BABBULS SPREKEN WANNEER JE HET BIJVOORBEELD OVER MONDEN HEBT.
10. DE KUSSENS ZIJN OPGEVULD MET VEREN/VERUN WAARDOOR ZE ZACHT AANVOELEN.
    OP DIE PLEK LIGGEN SOMS VEREN/VERUN VAN FAZANTEN EN PAUWEN.
11. VANWEGE ZIJN GEWICHTSTOENAME KRIJGT HIJ EEN SLECHTERE CONDITIE/CONDIETIE EN VOELT HIJ ZICH MINDER FIT.
    HIJ HEEFT TE WEINIG TIJD OM ZIJN CONDITIE/CONDIETIE WEER GOED OP PIJL TE KRIJGEN.
12. JAN VIST 'S OCHTENDS VROEG OP BAARZEN MET EEN HENGEL/HENGUL EN WAT AAS.
    DAT VOOORWERP OP DE KAST LIJKT OP EEN HENGEL/HENGUL VAN MIJN VADER.
13. OM VLIEGEN TE VANGEN MAAKT DIE SPIN EEN WEB/WEP DAT ER PRACHTIG UITZIET.
    HEEL VOORZICHTIG BETAST HIJ MET ZIJN VINGERS HET WEB/WEP EN VOELT HET PLAKKEN.
14. CARLA BEWAART HAAR OUDE POPPEN IN EEN HOUTEN KIST/KISD OP ZOLDER.
    OP DIT MOMENT BEVINDEN ZE ZICH IN EEN KIST/KISD ALS VERRASSING.
15. VOOR DE WOL SCHEREN DIE HERDERS IEDER VOORJAAR HUN SCHAPEN/SCHAPUN DIE ZICH ERTEGEN VERZETTEN.
    HET LIJKT MIJ EEN GOED IDEE OM EEN AANTAL SCHAPEN/SCHAPUN NAAR BUITEN TE LEIDEN.
16. IN DAT WEILAND MELKT DE BOER ZIJN KOEIEN/KOEJEN IEDERE DAG.
    VANDAAG SCHRIJFT HIJ EEN WERKSTUK OVER DE KOEIEN/KOEJEN EN STIEREN.
17. MET ZIJN VERZINSELS BEÏNVLOEDT DIE POLITICUS HET STEMGEDRAG VAN DE KIEZERS/KIESERS DIE ZICH LATEN MISLEIDEN.
    IK VRAAG ME AF OF ZIJ IETS WETEN VAN DE KIEZERS/KIESERS DIE NIET ZIJN GEKOMEN.
18. IN HET ZIEKENHUIS BEHANDELT DE DOKTER DE PATIËNT/PASIËNT DIE HET KOUD HEEFT.
    JE KUNT HET NIET MAKEN OM DE PATIËNT/PASIËNT LANG TE LATEN WACHTEN.
19. DE HOOGSTE LEIDER VAN DE KATHOLIEKE KERK IS DE PAUS/POUS DIE VEEL AANZIEN HEEFT.
    ZIJ WIL DIE KWESTIE HEEL GRAAG BESPREKEN MET DE PAUS/POUS IN EEN RUSTIGE OMGEVING.

20. DAT ZIEKE KIND HEEFT GRIEP MET KOORTS/KOORDS EN LIGT TE IJLEN.
NORMAAL HEEFT HIJ NOOIT LAST VAN KOORTS/KOORDS ALS HIJ ZIEK IS.
21. JAN KRUIDT HET VLEES ALTIJD MET PEPER EN ZOUT/ZAUT EN BAKT HET IN BOTER.
WAT HEN WEL OPVIEL WAS DAT ER VEEL ZOUT/ZAUT OVER DE FRIETJES WAS GESTROOID.
22. ZURE REGEN IS EEN ERNSTIGE VORM VAN VERVUILING/VERFUILING WAAR IETS TEGEN TE DOEN IS.
HET PRAATJE IN DIE ZAAL GAAT OVER VERVUILING/VERFUILING VAN DE LUCHT EN DE AARDE.
23. NA DE VAL LIEP DIE POES OP MAAR DRIE POTEN/POTUN EN HAD VEEL PIJN.
VOLGENS HEN HEEFT HET TOCH GEEN ZIN OM DE POTEN/POTUN KORTER TE MAKEN.
24. ER WAREN VEEL WETENSCHAPPERS IN DE STAD VANWEGE EEN CONGRES/CONCHRES DAT ERG BELANGRIJK WAS.
DE POSTERS LANGS DE WEG MAKEN RECLAME VOOR EEN CONGRES/CONCHRES DAT IN AUGUSTUS PLAATSVINDT.
25. NA HET MISHANDELEN VAN HET KLEINE MEISJE TOONDEN DE JONGENS GEEN BEROUW/BERAUW EN GAVEN HAAR DE SCHULD.
HET IS ZEKER NIET AARDIG VAN HET MEISJE DAT ZIJ GEEN BEROUW/BERAUW HEEFT EN NOG STEEDS PEST.
26. DE VRACHTWAGENS WAREN BETROKKEN BIJ EEN BOTSING/BODSING IN DIE DRUKKE STRAAT.
DROMEN KUNNEN BIJVOORBEELD GAAN OVER EEN BOTSING/BODSING WAARBIJ VEEL MENSEN OMKOMEN.
27. DIE PUBER HOUDT ZICH BEZIG MET HET OPVOEREN VAN ZIJN BROMMER/BROMMUR DIE NOGAL LANGZAAM IS.
OP DIE GEKREUKELDE OMSLAG STAAT EEN MOOI PLAATJE VAN EEN BROMMER/BROMMUR MET EEN JONGEN EROP.
28. DE AUTODIEFSTAL WERD VASTGELEGD DOOR EEN VERBORGEN CAMERA/CAMURA WAARDOOR DE DIEF GEPAKT WERD.
HET LIJKT MIJ NIET NODIG OM EEN CAMERA/CAMURA TE KOPEN VOOR DE CURSUS.
29. DOOR HET ZAND SNEED DE SLIPPER TUSSEN HAAR TENEN/TENUN WAT HAAR PIJN DEED.
HET MEISJE MERKT NIET DAT ZIJ MET HAAR TENEN/TENUN IN HET GLAS STAAT.
30. HET VERLIEFDE PAAR KEEK NAAR DE STERREN AAN DE HEMEL/HEMUL EN WAS VOLMAAKT GELUKKIG.
ZIJ HOPEN DAT HET ECHT ZO IS DAT DE HEMEL/HEMUL BESTAAT EN MOOI IS.
31. DE VERKOPER HIELP GEDULDIG DE LASTIGE KLANTEN/KLANTUN DIE ONBELEEFD WAREN.
ZIJ WILLEN LIEVER NIET DAT DE KLANTEN/KLANTUN DE ROTZOOI ZIEN.
32. BIJ DE GEBOORTE VAN HUN KINDJE KREEG IEDEREEN BESCHUIT MET MUISJES/MUISJUS OM HET TE VIEREN.
IN HET VERHAAL WORDT UITVOERIG EEN GEBEURTENIS BESCHREVEN WAARIN VERSCHILLENDE MUISJES/MUISJUS NAAR KAAS ZOEKEN.
33. HET WRAK WERD VAN DE ZEEBODEM GEHAALD DOOR BEKWAME DUIKERS/DUIKURS DIE GOED GETRAIND WAREN.
DIE KINDEREN LUISTEREN HEEL GRAAG NAAR LANGE VERHALEN OVER DUIKERS/DUIKURS DIE NAAR SCHATTEN ZOEKEN.
34. IN HET PARK VOERDEN DE KINDEREN DE EENDJES/EENTJES DIE HET KOUD HADDEN.
IK HEB ECHT GEEN IDEE WAAROM DE EENDJES/EENTJES UIT DE VIJVER BLIJVEN.
35. VANWEGE ONTSTEKINGEN TROK DE TANDARTS HAAR ACHTERSTE KIEZEN/KIESEN DIE HELEMAAL ZWART WAREN.
NORMAAL GESPROKEN GEBEURT HET NOOIT DAT ZIJN KIEZEN/KIESEN PIJN DOEN MET KAUWEN.
36. DAAR WAAR JAN ZIJN HOOFD STOOTTE ZIT NU EEN GROTE BULT/BULD DIE HEM ERG PIJN DOET.
DE ZOON DIE NOG BIJ ZIJN MOEDER INWOONT HEEFT EEN BULT/BULD DIE SINDS GISTEREN ONTSTOKEN IS.
37. NA EEN DAG ZONDER VOEDSEL HAD JAN HONGER/HONGUR EN WEINIG ENERGIE.
HET GEBEURT NIET VAAK DAT MEN HIER HONGER/HONGUR OF DORST HEEFT.
38. IN DAT MUSEUM HANGEN VEEL SCHILDERIJEN/SCHILDERIJUN DIE ERG BIJZONDER ZIJN.
IN DE KELDER LIGGEN VEEL SCHILDERIJEN/SCHILDERIJUN DIE ERG STOFFIG ZIJN.
39. OP KONINGINNEDAG HANGEN ER BIJ VEEL HUIZEN VLAGGEN/VLAGGUN BUITEN AAN EEN STOK.
OP STRAAT HOREN ZIJ TOEVALLIG OVER MOOIE VLAGGEN/VLAGGUN DIE TE KOOP ZIJN.
40. OP ZIJN VERJAARDAG SMULLEN DE GASTEN VAN TAART/TAARD EN DRINKEN KOFFIE.
NA LANG NADENKEN KIEST ZE VOOR DE TAART/TAARD MET WITTE CHOCOLADE.
41. DE KLEUTER PLAKT HET DOOSJE MET LIJM/LEIM SPECIAAL VOOR KINDEREN.
DE HANDELAAR PAKT DE DOOS MET LIJM/LEIM EN LOOPT NAAR ZIJN KRAAM.
42. DIE KOKS ETEN DE HEERLIJKE SOEP MET LEPELS/LEPULS EN GENIETEN ERVAN.
DIE KOOPMANNEN PAKKEN SNEL DE KRATTEN MET LEPELS/LEPULS OM NOG TE VERKOPEN.

43. MOEDER STOPT DE SOKKEN MET NAALD EN DRAAD/DRAAT WANNEER ER EEN GAT IN ZIT.
    DE VROUW IS HAASTIG OP ZOEK NAAR DRAAD/DRAAT OM DE KAPOTTE BROEK TE MAKEN.
44. HET WASSENDE ZEEWATER WORDT TEGENGEHOUDEN DOOR DIJKEN/DEIKEN DIE LANG GELEDEN WERDEN GEBOUWD.
    GELUKKIG HEBBEN DIE MENSEN BIJNA ALLE DIJKEN/DEIKEN VERZWAARD VOOR DE STORM LOSBARST.
45. IN HAAR NIEUWE SALON LAKT DE BEKWAME MANICURE NAGELS/NAGULS IN DE FELSTE KLEUREN.
    VOORZICHTIG RAAKT HET MEISJE MET HAAR VINGER DE NAGELS/NAGULS AAN DIE GELAKT ZIJN.
46. VANWEGE DE GROTE WONINGNOOD BOUWT MEN VEEL HUIZEN/HUISEN OP EEN KLEINE OPPERVLAKTE.
    OP DE TENTOONSTELLING ZIET HIJ FOTO'S VAN HUIZEN/HUISEN VAN VROEGER EN NU.
47. VOOR DE SPIEGEL STIFT HET MEISJE HAAR LIPPEN/LIPPUN MOOI ROOD.
    OP DE TEKENING IN HET BOEK STAAN LIPPEN/LIPPUN EN TANDEN.
48. DE MEESTE STUDENTEN VAN DIE UNIVERSITEIT WONEN OP KAMERS/KAMURS EN GAAN VEEL UIT.
    WIJ WILLEN NATUURLIJK HEEL ERG GRAAG DAT DE KAMERS/KAMURS UITKIJKEN OP DE ZEE.
49. DAN IS ER GROTE UITVERKOOP IN DIE WINKEL/WINKUL AAN DE RAND VAN HET DORP.
    HIJ VINDT HET ERG BELANGRIJK DAT DE WINKEL/WINKUL DE NAAM KRIJGT VAN ZIJN VADER.
50. DIE PRACHTIGE VOS GAAT VOOR DE JAGER OP DE VLUCHT/VLUGT EN STEEKT DE WEG OVER.
    DIE GROEP MENSEN IS DRUK IN GESPREK OVER DE VLUCHT/VLUGT VAN DE TWEE GEVAARLIJKE CRIMINELEN.
51. NA HET ETEN BLEVEN DE VRIENDEN ZITTEN AAN DE TAFEL/TAVEL EN SPEELDEN EEN SPEL.
    HIJ ZEGT DAT HET MISSCHIEN MOGELIJK IS OM DE TAFEL/TAVEL WAT KLEINER TE MAKEN.
52. VAN DIE FLAT WAST DE GLAZENWASSER IEDERE MAAND DE RAMEN/RAMUN DIE ERG HOOG ZIJN.
    WAT DE VREEMDE MAN PROBEERT TE BESCHRIJVEN ZIJN DE RAMEN/RAMUN VAN GLAS IN LOOD.
53. DAT CHRISTELIJKE MEISJE LEEST IEDERE AVOND EEN STUKJE UIT DE BIJBEL/BEIBEL SAMEN MET HAAR MOEDER.
    DE SPRAAKZAME VROUWEN WILLEN HEEL GRAAG IETS VERTELLEN OVER DE BIJBEL/BEIBEL EN HUN GELOOF.
54. DIE VROUWEN IN KLEDERDRACHT LOPEN OP KLOMPEN/KLOMPUN ZONDER SOKKEN.
    DE VROUW HEEFT VEEL GEHOORD OVER KLOMPEN/KLOMPUN MET BLOEMMOTIEF.
55. VANWEGE DE LANGE FILES GAAT ZIJ NAAR HAAR WERK MET DE TREIN/TRIJN WAARDOOR ZE SNELLER IS.
    IN DE KLAS SCHRIJFT DE LEERLING EEN LANG OPSTEL OVER EEN TREIN/TRIJN EN ANDERE SOORTEN VERVOERMIDDELEN.
56. ELKE WEEK KRIJGEN HAAR PLANTEN WATER/WATUR EN EENS IN DE MAAND VOEDING.
    DE GROEP HEEFT HET OVER WATER/WATUR DAT GEZUIVERD WORDT IN DIE CENTRALE.
57. BIJ EEN VISGERECHT MOET MEN OPPASSEN VOOR DE GRATEN/GRATUN DIE GEVAARLIJK ZIJN.
    VOL ONGELOOF KIJKT HET KLEINE KIND NAAR DE GRATEN/GRATUN VAN DE VIS.
58. OP KOOPAVOND IS HET ERG DRUK IN DE STAD/STAT MET WINKELENDE MENSEN.
    DE MENSEN ZIJN ONDER DE INDRUK VAN DE STAD/STAT EN HAAR HISTORIE.
59. MENSEN MET DE ZIEKTE VAN PFEIFFER HEBBEN VAAK OPGEZETTE KLIEREN/KLIERUN EN ZIJN MOE.
    IN DE GROEP HEBBEN ZE HET DIE OCHTEND OVER KLIEREN/KLIERUN IN HET LICHAAM.
60. MET EEN STOLP DOOFT JAN DE KAARSEN/KAARSUN DIE AL BIJNA WAREN OPGEBRAND.
    SOMMIGE MENSEN KIJKEN AANDACHTIG NAAR DE KAARSEN/KAARSUN DIE EEN GELE GLOED VERSPREIDEN.
61. IN DIE FABRIEK BOTTELT MEN WIJN IN FLESSEN/FLESSUN DIE EEN GROENE KLEUR HEBBEN.
    DE VADER VRAAGT HEM NAAR VERSCHILLENDE SOORTEN FLESSEN/FLESSUN EN KOOPT UITEINDELIJK DE DUURSTE.
62. IN DAT PRACHTIGE BOS GROEIEN ZELDZAME BOMEN/BOMUN DIE AL ERG GROOT ZIJN.
    HET KIND HOUDT EEN SPREEKBEURT OVER BOMEN/BOMUN IN HET TROPISCH REGENWOUD.
63. NA EEN BLOEIENDE CARRIÈRE GAAT VADER OP ZIJN ZESTIGSTE MET PENSIOEN/PENSJOEN OM TE GENIETEN VAN ZIJN VRIJE TIJD.
    IN DIE ZAAL WORDT EEN KORTE VOORLICHTING GEGEVEN OVER HET PENSIOEN/PENSJOEN DAT DE WERKNEMERS PER DIRECT GAAN OPBOUWEN.
64. DE WIJNRANKEN HANGEN KROM DOOR DE TROSSEN DRUIVEN/DRUIFEN DIE RIJPEN IN DE ZON.
    IN DE SUPERMARKT VINDT DE MOEDER GOEDE DRUIVEN/DRUIFEN VOOR IN HAAR ZELFGEMAAKTE FRUITSALADE.
65. JAN START ALS KLEINE ONDERNEMER ZIJN EIGEN BEDRIJF/BEDREIF IN AUTO-ONDERDELEN.
    AAN DE TELEFOON SPREKEN ZIJ OVER EEN BEDRIJF/BEDREIF IN EUROPA.

66. DE KIPPEN VAN DIE BOER LEGGEN VEEL EIEREN/EIERUN EN SCHARRELEN WAT ROND.
    DE BABY KIJKT UITERST GEFASCINEERD NAAR DE EIEREN/EIERUN DIE OP TAFEL LIGGEN.
67. IN DAT LAND KRIJGEN OVERTREDERS VAN DE WET GEEN EERLIJK PROCES/PROSES WAARIN IEDEREEN HETZELFDE BEHANDELD WORDT.
    DIE MIDDAG PRESENTEERT DE COMMISSIE EEN DIK RAPPORT OVER EEN PROCES/PROSES DAT EEN JAAR HEEFT GEDUURD.
68. DE STRATENMAKER PLAVEIT DIE BREDE STRAAT MET STENEN/STENUN DIE ZWART GEKLEURD ZIJN.
    HIJ MAAKT RUZIE MET HEM OVER DE STENEN/STENUN DIE NIET AFGELEVERD ZIJN.
69. DE MIJNEN IN DIE STREEK LEVEREN KOLEN/KOLUN DIE VEEL GELD OPBRENGEN.
    DE JONGEN GEEFT DE VROUW ENKELE KOLEN/KOLUN VOOR DE HELE WEEK.
70. IN HET SPROOKJESBOS VLIEGEN DE HEKSEN MET HUN BEZEMS/BESEMS TUSSEN DE BOMEN DOOR.
    OMDAT HET NIET ANDERS KAN PROBEERT HIJ MET BEZEMS/BESEMS HET VUUR TE DOVEN.
71. BUITEN ROOKT JAN EEN PAAR SIGARETTEN/SIGARETTUN IN DE KOU.
    VERVOLGENS PAKTE ZIJ EEN AANTAL SIGARETTEN/SIGARETTUN UIT HET PAKJE.
72. DAT VERLOOFDE STEL IS DRUK BEZIG MET DE UITNODIGINGEN VOOR DE BRUILOFT/BRUILOFD DIE VOLGENDE MAAND ZAL PLAATSVINDEN.
    HET WAS OOK TE MOOI OM WAAR TE ZIJN DAT DE BRUILOFT/BRUILOFD HELEMAAL ZONDER REGEN ZOU VERLOPEN.
73. ZIJ HEEFT ALS BIJBAAN HET INVOEREN VAN GEGEVENS IN DE COMPUTER/COMPUTUR VAN EEN POSTORDERBEDRIJF.
    IN DE WINKEL WILDE DE VROUW MEER WETEN OVER EEN COMPUTER/COMPUTUR DIE TE KOOP STOND.
74. HAAR WALKMAN DEED HET NIET MEER VANWEGE DE BATTERIJ/BATTEREI WAARVAN ZIJ BAALDE.
    IK DACHT DAT HET ONMOGELIJK WAS OM DE BATTERIJ/BATTEREI NOG TE VERVANGEN.
75. UIT VERLIEFDHEID KIJKT ZIJ HEM DIEP IN DE OGEN/OGUN EN BLOOST.
    HET VIEL HEN TOEN WEL OP DAT DE OGEN/OGUN SCHEEF STONDEN.
76. DE LERAAR SCHRIJFT OP HET BORD MET EEN KRIJTJE/KREITJE HET HUISWERK VOOR MORGEN.
    AFWEZIG STAARDE HET JONGE MEISJE LANG NAAR EEN KRIJTJE/KREITJE OP TAFEL.
77. NA DE LUNCH ZET MOEDER DE VLEESWAREN TERUG IN DE KOELKAST/KOELKASD DIE ERG KOUD IS.
    ZIJ VONDEN HET WEL MOEILIJK MAAR KOZEN TOCH VOOR EEN KOELKAST/KOELKASD MET EXTRA VRIESVAK.
78. IN DIE HOGE FLAT MOET JE NAAR BOVEN MET DE LIFT/LIFD DIE SOMS BLIJFT HANGEN.
    DE KINDEREN IN DE KLAS LEERDEN DIE DAG DAT EEN LIFT/LIFD AAN STAALKABELS HANGT.
79. IN DE STALLEN VAN DIE MANEGE STAAN HAAR PAARDEN/PAARDUN DIE VEEL MENSEN BEWONDEREN.
    DE MAN SCHREEF IN HET VERSLAG DAT DE PAARDEN/PAARDUN DOOR HEM WERDEN MISHANDELD.
80. IN DIE RIVIER VANGT JAN ZOMERS VEEL VISSEN/VISSUN VOOR IN ZIJN AQUARIUM.
    DIE MENSEN SCHROKKEN HEEL ERG VAN DE VISSEN/VISSUN DIE OPEENS OMHOOG SPRONGEN.
81. TIJDENS HAAR BRUILOFT WORDT HET ETEN OPGEDIEND DOOR OBERS/OBURS DIE NETJES GEKLEED ZIJN.
    WANHOPIG WENDDEN DIE MENSEN ZICH TOT EEN PAAR OBERS/OBURS OM HEN TE HELPEN.
82. IN DE IDEALE WERELD GEVEN DE RIJKEN GELD AAN DE ARMEN/ARMUN EN IS IEDEREEN GELIJKWAARDIG.
    HOEWEL DIE MAN NORMAAL GESPROKEN NIET VEEL GEEFT OM DE ARMEN/ARMUN DONEERDE HIJ TOCH GELD.
83. HIJ LIET ZIJN HAAR KORT KNIPPEN DOOR DE KAPPER/KAPPUR DIE ERG GEHAAST OVERKWAM.
    HIJ VOND HET HELEMAAL NIET ERG OM DE KAPPER/KAPPUR EVEN THUIS TE BRENGEN.
84. JAN DRINKT KOFFIE MET MELK EN SUIKER/SUIKUR VOORDAT HIJ GAAT WERKEN.
    IN GEDACHTEN VERZONKEN PAKTE HIJ DE SUIKER/SUIKUR EN VULDE HET SCHAALTJE.
85. NA HET SPORTEN SPUIT JAN DEODORANT ONDER ZIJN OKSELS/OKSULS WANNEER HIJ GEDOUCHT HEEFT.
    DE DOKTER KEEK NOG EENS GOED NAAR ZIJN OKSELS/OKSULS MAAR ZAG NIETS VREEMDS.
86. OP DE FRIESE MEREN BOLDEN DE WINDVLAGEN DE ZEILEN/ZEILUN EN KREEG DE BOOT VEEL VAART.
    DIE MENSEN VONDEN HET ERG INTERESSANT DAT DE ZEILEN/ZEILUN VAN HET GROTE SCHIP GEHESEN WERDEN.
87. HET MEISJE VERSTOPTE HAAR GELD IN EEN KISTJE MET DUBBELE BODEM/BODUM DAT ZE VAN HAAR OMA KREEG.
    IN DE HAAST VERGAT HET KLEINE MEISJE DIE MIDDAG DE BODEM/BODUM VAN DE BOOT SCHOON TE MAKEN.
88. BIJ LANGE AFWEZIGHEID SCHREEF HIJ ZIJN GELIEFDE BRIEVEN/BRIEFEN VOL LIEVE WOORDEN.
    HET VIEL NIET MEE OM ECHT ALLE BRIEVEN/BRIEFEN GRONDIG TE LEZEN.

89. VROEGER LEEFDEN GEVANGENEN OP WATER EN BROOD/BROOT DAT BIJNA BEDORVEN WAS.
HIJ ZOEKT IN DE SCHAPPEN NAAR BROOD/BROOT MAAR VINDT HET NIET.
90. IN DE WEI PLUKTE HET MEISJE VAAK BLOEMEN/BLOEMUN IN DE ZON.
NADAT ZIJ HADDEN RONDGEKEKEN VONDEN ZIJ MOOIE BLOEMEN/BLOEMUN VOOR OP TAFEL.
91. BENEVELD DOOR DRANK STOND HIJ TE WANKELEN OP ZIJN BENEN/BENUN EN VIEL UITEINDELIJK OM.
VLUCHTIG LIET HIJ ZIJN KRITISCHE BLIK GAAN OVER DE BENEN/BENUN VAN HET MOOIE MODEL.
92. GISTEREN GINGEN DE VRIENDEN EEN AVONDJE GOKKEN IN EEN CASINO/CASIENO EN HADDEN VEEL PLEZIER.
OP DE TELEVISIE ZAGEN ZIJ EEN PROGRAMMA OVER EEN CASINO/CASIENO MET EEN GROOT DAKTERRAS.
93. TIJDENS DIE VOETBALWEDSTRIJD ZATEN ER VEEL SUPPORTERS OP DE TRIBUNE/TRIEBUNE DIE BIJNA INSTORTTE.
HET HEEFT HEN VEEL TIJD EN INSPANNING GEKOST MAAR DE TRIBUNE/TRIEBUNE IS NU EINDELIJK AF.
94. OP VAKANTIE HAD VADER VEEL MOEITE MET HET OPZETTEN VAN DE TENT/TEND EN WAS SLECHT GEHUMEURD.
HIJ VERSTOND HAAR NIET GOED TOEN ZE HET HAD OVER DE TENT/TEND DIE ZE WILDE KOPEN.
95. DIE GEDULDIGE VISSER ZAT UREN TE KIJKEN NAAR ZIJN RODE DOBBER/DOBBUR DIE RUSTIG OP HET WATER LAG.
NA LANG ZOEKEN IN DE SCHUUR VOND HIJ UITEINDELIJK EEN DOBBER/DOBBUR DIE HIJ IN ZIJN ZAK STOPTE.
96. OPA SCHREEF DE VERJAARDAGEN VAN ZIJN KLEINKINDEREN OP DE KALENDER/KALENDUR OM ZE NIET TE VERGETEN.
WAT IN DEZE WINKEL VEEL VERKOCHT WORDT IS DE KALENDER/KALENDUR MET DAAROP VERSCHILLENDE SOORTEN DIEREN.
97. DIE BEDIENDE NAM DE LEGE BORDEN MEE OP EEN DIENBLAD/DIENBLAT DAT HIJ BIJNA LIET VALLEN.
NADAT HIJ VERSCHEIDENE WINKELS WAS AFGEWEEST KOCHT HIJ EEN DIENBLAD/DIENBLAT EN ONDERZETTERS VOOR ZIJN MOEDER.
98. NA HUN ACHTTIENDE LEVENSJAAR GINGEN DE JONGENS IN MILITAIRE DIENST/DIENSD OM HET LAND TE KUNNEN VERDEDIGEN.
HIJ DACHT GELUKKIG NET OP TIJD AAN DE DIENST/DIENSD DIE HIJ DIE AVOND MOEST DRAAIEN.
99. NA HET DINER RIEP VADER DE KELNER VOOR DE REKENING/REKUNING DIE LAAT KWAM.
UITERST GECONCENTREERD TUURDE DE MAN DIE DAG NAAR DE REKENING/REKUNING DIE NIET KLOPTE.
100. DE HELDERZIENDE VOORSPELDE HET KIND EEN GOEDE TOEKOMST/TOEKOMSD MET WEINIG PROBLEMEN IN DE LIEFDE.
HIJ WILDE MET HEM PRATEN OVER DE TOEKOMST/TOEKOMSD VAN DE STICHTING EN HET BEDRIJF.
101. DAT PAARD WERD TIJDENS HET NOODWEER GETROFFEN DOOR DE BLIKSEM/BLIKSUM EN STIERF.
DE MAN WERD DIE OCHTEND EVEN AFGELEID DOOR DE BLIKSEM/BLIKSUM EN VERONGELUKTE.
102. TIJDENS DE UITLEG BLEEK JAN TRAAG VAN BEGRIP/BECHRIP MAAR ERG HUMORISTISCH.
HIJ SCHREEF EEN UITGEBREIDE UITEENZETTING OVER HET BEGRIP/BECHRIP RECHTVAARDIGHEID VOOR IEDEREEN.
103. DIE TOERIST GING OP VAKANTIE MET EEN VERLOPEN PASPOORT/PASPOORD EN WERD AANGEHOUDEN BIJ DE DOUANE.
ZE WIST NIET WAT TE DOEN MET EEN PASPOORT/PASPOORD DAT IN HET WATER WAS GEVALLEN.
104. NA EEN LANGDURIG APPLAUS KWAM DE ZANGER TERUG VOOR EEN TOEGIFT/TOECHIFT WAAR HET PUBLIEK OM VROEG.
HET KOMT EIGENLIJK BEST WEL VAAK VOOR DAT ER EEN TOEGIFT/TOECHIFT WORDT GEGEVEN DOOR DIE BAND.
105. VOOR OMA'S VERJAARDAG DACHT JAN AAN EEN KAARTJE OP DE POST/POSD MET EEN GELUKWENS.
HELAAS KON DIE JONGEN ONS NIET VEEL VERTELLEN OVER DE POST/POSD DIE WAS ZOEKGERAAKT.
106. VANWEGE GELDGEBREK KOOS ZIJ VOOR BETALING OP TERMIJN/TERMEIN BIJ DE AANKOOP VAN EEN WASMACHINE.
OP HET WITTE VEL PAPIER STOND EEN TERMIJN/TERMEIN VOORGESTELD DIE TOTAAL NIET REDELIJK WAS.
107. IN DE KEUKENHOF FOTOGRAFEERDEN DE JAPANSE TOERISTEN DE TULPEN/TULPUN DIE PRACHTIG WAREN.
DIE PERSOON KEEK NOG EENS GOED NAAR DE TULPEN/TULPUN IN DIE KAS.
108. OM DE BIZON TE VANGEN SCHOOT DE INDIAAN EEN PIJL/PEIL IN ZIJN BORST.
TUSSEN ALLE ROMMEL OP ZIJN KAMER VOND HIJ EEN PIJL/PEIL MET SCHERPE PUNT.
109. DE TE STRAKKE TROUWRINGEN VEROORZAAKTEN EEN AFKNELLING VAN HUN VINGERS/VINGURS DIE BLAUW WERDEN.
ZIJ SCHROK TOEN ZIJ HET BERICHT KREEG DAT DE VINGERS/VINGURS MOESTEN WORDEN GEAMPUTEERD.
110. DE WERKGEVER VREESDE VOOR EEN STAKING DOOR ZIJN WERKNEMERS/WERKNEMURS DIE GEEN GELD MEER HADDEN.
TIJDENS DE LUNCH SPRAKEN DE VRIENDEN OVER DE WERKNEMERS/WERKNEMURS DIE BIJ HET BEDRIJF WEGGINGEN.
111. NA EEN AVOND UITGAAN MET TEVEEL BIERTJES HAD JAN EEN ZWARE KATER/KATUR EN VOELDE ZICH BEROERD.
VOOR DIE VROUW WAS HET DE EERSTE KEER DAT ZIJ EEN KATER/KATUR HAD NA HET UITGAAN.

112. MET HAAR NAGEL TROK MOEDER EEN LADDER IN HAAR PANTY/PENTY DIE MOOI WIT WAS.
DIE MEVROUW IN DE VORIGE WINKEL NOEMDE HET EEN PANTY/PENTY EN NIET EEN MAILLOT.
113. DE AUTOCOUREUR SCHOOT TIJDENS DE RACE UIT DE BOCHT/BOGT EN RAAKTE ZWAAR GEWOND.
DIE PERSONEN VONDEN DAT HET NET LEEK ALSOF DE BOCHT/BOGT VEEL SCHERPER WAS GEWORDEN.
114. TIJDENS HET CONCERT KEKEN DE VIOLISTEN NAAR HET STOKJE VAN DE DIRIGENT/DIRIGEND EN WAREN UITERST GECONCENTREERD.
TIJDENS DE INFORMELE BIJEENKOMST LEGDE ZIJ HET STUK VOOR AAN EEN DIRIGENT/DIRIGEND DIE HET GOED BEKEEK.
115. BIJ DIE BEGROETING KUSTE ZIJN VERLOOFDE HEM OP DE MOND/MONT EN STREELDE ZIJN HAAR.
TIJDENS DE CURSUS MAAKTE HIJ EEN SCHETS VAN EEN MOND/MONT EN KLEURDE HET IN.
116. DIE NACHT VEROORZAAKTE DE DRONKEN AUTOMOBILIST EEN ONGELUK/ONGULUK OP DE STRAAT.
TIJDENS HET WANDELEN VERTELDEN ZIJ DAT EEN ONGELUK/ONGULUK HEM FATAAL WERD.

Syntactic condition (syntactic correct/syntactic incorrect)

1. DE UIT NEDERLAND AFKOMSTIGE VOETBALLER VERTOEFT/VERTOEVEN NU IN SPANJE.
2. HET SLANKE MODEL OP HET PODIUM GLIMLACHT/GLIMLACHEN NAAR DE FOTOGRAAF.
3. DIE DAPPERE EN EDELE RIDDER SPRONG/SPRONGEN OP ZIJN PAARD EN GALOPPEERDE WEG.
4. ALHOEWEL DAT KLEINE MEISJE MEESTAL HEIMWEE HEEFT/HEBBEN GAAT ZE TOCH BIJ OMA LOGEREN.
5. DE VROME DOMINEE VAN DIE PROTESTANTSE KERK PREEKT/PREKEN EN VERHEFT DAARBIJ ZIJN STEM.
6. DE BEELDSCHONE BLONDE ASSISTENTE VAN DE GOOCHELAAR STAPTE/STAPTEN IN DE KIST EN VERDWEEN IN HET NIETS.
7. DE GROOTVADER DIE ZIJN KLEINKIND VOOR HET SLAPEN EEN VERHAAL VERTELT/VERTELLEN HEEFT VEEL FANTASIE.
8. DE KILLE MOORDENAAR DIE OVER ZIJN LAATSTE SLACHTOFFER DROOMT/DROMEN HEEFT EEN GLIMLACH OP ZIJN GEZICHT.
9. DE BETROKKEN MANAGER DIE ZELF MET DE BETREFFENDE MEDEWERKER SPRAK/SPRAKEN BELOOFDE SNEL VERBETERING.
10. DE NIEUWE JUF VAN GROEP ZEVEN IS/ZIJN STRENG MAAR ZEKER WEL RECHTVAARDIG.
11. DE ENTHOUSIASTE DIRECTEUR VAN HET NIEUWE BEDRIJF BELT/BELLEN MET POTENTIËLE KLANTEN.
12. DE AARDIGE ZUSTER DIE AL LANG IN HET ZIEKENHUIS WERKTE/WERKTEN PRIKTE IN ZIJN ADER.
13. DE OUDE MAN DIE 'S OCHTENDS MET ZIJN HOND WANDELT/WANDELEN STAAT AL VROEG OP.
14. HET IJVERIGE PERSONEEL VAN DE BAKKER SNIJDT/SNIJDEN HET BROOD EN DOET HET IN ZAKKEN.
15. DIE BLAUWE VULPEN MET DE RODE DOP SCHRIJFT/SCHRIJVEN HELEMAAL NIET FIJN.
16. DE SMERIGE OLIE DIE UIT DE KAPOTTE TANKER LEKTE/LEKTEN VERVUILDE HET STRAND.
17. DE WEKKER IN DE SLAAPKAMER GAAT/GAAN AF EN WEKT DE MENSEN.
18. ZIJN TIJDELIJKE CONTRACT DAT DEZE MAAND AL AFLOOPT/AFLOPEN KAN NIET WORDEN VERLENGD.
19. HET RONDE WITTE BORD VAN HEEL DUN PORSELEIN BRAK/BRAKEN TIJDENS DE AFWAS.
20. DE GROTE TRUCK DIE DAAR VAN DE VEERBOOT RIJDT/RIJDEN IS VAN MIJN VADER.
21. DE ROZE SHAMPOO IN DIE DOORZICHTIGE FLES ROOK/ROKEN NAAR LAVENDEL.
22. HET OPGEREKTE ELASTIEK OM DE BROODTROMMEL KNAPTE/KNAPTEN EN BELANDDE OP DE GROND.
23. DE KRACHTIGE ORKAAN DIE TEGEN DE MIDDAG HET EILAND BEREIKT/BEREIKEN ZAL WAARSCHIJNLIJK VEEL SCHADE AANRICHTEN.
24. HET DURE CADEAU DAT ECHTER NIET IN DE SMAAK VIEL/VIELEN KON GELUKKIG WORDEN GERUILD.
25. DE KLEINE WINKEL DIE VANWEGE HET NADERENDE FAILLISSEMENT SLOOT/SLOTEN DEED ALLES IN DE UITVERKOOP.
26. DIE MOOIE ROZENSTRUIK IN DE AANGRENZENDE TUIN BLOEIT/BLOEIEN VOLOP EN TREKT BIJEN AAN.
27. DE NIEUWE LAMP DIE NOG STEEDS IN DE VERPAKKING ZIT/ZITTEN IS ERG BREEKBAAR.
28. DE GOEDKOOPSTE JURK VAN DIE NIEUWE COLLECTIE KOSTTE/KOSTTEN MAAR LIEFST TACHTIG EURO.
29. DE EERSTE LES IN HET OPGEKNAPTE WIJKCENTRUM BEGON/BEGONNEN DIE OCHTEND OM ACHT UUR.
30. DE SPECIAAL VOOR HET FEEST OVERGEKOMEN GASTEN BLIJVEN/BLIJFT OOK NOG HET HELE WEEKEND.
31. DE BLIJE TRAINERS VAN DE WINNENDE TURNSTERS VIERDEN/VIERDE DE OVERWINNING MEE EN WAREN ERG TEVREDEN.
32. HOEWEL DIE LUIE JONGENS EIGENLIJK NIET GRAAG FIETSEN/FIETST DOEN ZE ER NIET MOEILIJK OVER.

33. DE BIOLOGISCHE MOEDERS VAN DE GEADOPTEERDE KINDEREN WONEN/WOONT IN BOLIVIA EN HEBBEN NOG STEEDS VERDRIET.
34. DE OUDERS VAN DIE BRUTALE EN ONGEHOORZAME KINDEREN WISTEN/WIST NIETS VAN OPVOEDEN AF.
35. DE VELE TOESCHOUWERS DIE AANDACHTIG NAAR DE ACTEURS KIJKEN/KIJKT VERMAKEN ZICH PRIMA.
36. DE HOGE DIPLOMATEN DIE IN HET GEHEIM VOOR DE AMERIKANEN SPIONEERDEN/SPIONEERDE MOESTEN MOSKOU VERLATEN.
37. DE STOERE BOUWVAKKERS DIE GRAAG NAAR DE JONGE MEISJES FLUITEN/FLUIT KRIJGEN GEEN RESPONS.
38. DE VADERS DIE SIERLIJK MET HUN JONGSTE DOCHTERS DANSEN/DANST HEBBEN ER VEEL PLEZIER IN.
39. DE RECHERCHEURS DIE EEN LANGE TIJD MET DE ARRESTANTEN PRAATTEN/PRAATTE KWAMEN NIET VEEL VERDER.
40. DE VELE HONDERDEN BEZOEKERS VAN DE FEESTELIJKE FESTIVITEITEN KOMEN/KOMT VOORAL UIT DE OMGEVING.
41. DE BEROEMDE ARTIESTEN DIE GRAAG VOOR HUN UITZINNIGE FANS ZINGEN/ZINGT STAAN ALWEER KLAAR OP HET PODIUM.
42. DE ONVERMOEIBARE REDDINGSWERKERS DIE AL ENKELE DAGEN NAAR OVERLEVENDEN ZOEKEN/ZOEKT ZIJN HIERVOOR SPECIAAL OPGELEID.
43. DE ZWART GEVLEKTE GEITEN VAN DIE TWEE HERDERS GRAASDEN/GRAASDE IN DE BERM EN STAKEN DE WEG NIET OVER.
44. DE WAAKSE HONDEN VAN ONZE NIEUWE BUREN BLAFFEN/BLAFT ALTIJD HARD NAAR ONSCHULDIGE PASSANTEN.
45. DE MET ROOD FLUWELEN STOF BEKLEDE STOELEN STAAN/STAAT ACHTER IN DE WINKEL.
46. DE GROTE WIEKEN VAN DE HOGE WINDMOLENS DRAAIDEN/DRAAIDE HARD IN HET ROND.
47. DIE OUDE EN VERSLETEN BLAUWE SLOFFEN MOETEN/MOET NU ECHT WORDEN WEGGEGOOID.
48. DE ZWARE STENEN DIE VAN DE HELLINGEN NAAR BENEDEN ROLDEN/ROLDE BESCHADIGDEN DE VOERTUIGEN.
49. DIE TROPISCHE PLANTEN MET GROTE ROZE BLOEMEN GROEIDEN/GROEIDE SNEL DOOR HET VELE WATER.
50. DE SCHONE KLEREN EN HANDDOEKEN HANGEN/HANGT AAN DE WASLIJN OM TE DROGEN.
51. DE GROTE FABRIEKEN DIE ILLEGAAL IN DE RIVIEREN LOZEN/LOOST ONTVANGEN EEN HOGE BOETE.
52. DE ZWARE DEUREN VAN DIE GOED BEVEILIGDE KLUIZEN KONDEN/KON OPEN ALS DAT NODIG WAS.
53. DE AUTO'S DIE NIET VOOR DE RODE STOPLICHTEN STOPPEN/STOPT WORDEN VERDEROP AANGEHOUDEN.
54. DE HOUTEN SLEETJES OP DE STEILE HELLINGEN GLEDEN/GLEED NAAR BENEDEN EN MAAKTEN VEEL VAART.
55. DE VERSCHILLEND GEKLEURDE BORDJES AAN DE MUREN WIJZEN/WIJST DE WEG EN LICHTEN OP IN HET DONKER.
56. DE KRACHTIGE BOMMEN DIE PLOTSELING IN DE GEBOUWEN ONTPLOFTEN/ONTPLOFTE RICHTTEN VEEL SCHADE AAN.
57. DE WOESTE GOLVEN DIE OVER DE HOGE DUINEN SLOEGEN/SLOEG MAAKTEN DE BADGASTEN BANG.
58. DE SCHITTERENDE MET GOUD EN ZILVER AFGEZETTE JUWELEN LIGGEN/LIGT IN DE VITRINE EN WORDEN BEWAAKT.

APPENDIX 3: EXPERIMENTAL MATERIALS CHAPTER 5 & 6

Visual degradation condition

1. DIE PERSOON WEET HEEL VEEL OVER REISKOSTEN IN DAT LAND.
2. IN DIE PLASTIC ZAK ZIT EEN KILO VIS VOOR HET AVONDETEN.
3. ZIJ ZIJN VAN MENING DAT HET DODENTAL HOGER IS.
4. ZIJ VERBAAST ZICH NOG OVER DE DIEFSTAL DIE OVERDAG PLAATSVOND.
5. DIE SCHRIJFSTER WERKT AAN EEN VERHAAL OVER MUZIEK DIE DE MENSEN HYPNOTISEERT.
6. ZIJ VINDEN HET LEUK OM ALLERLEI TALEN MET ELKAAR TE SPREKEN.
7. HET INTERESSEERT HEM NIET DAT DE ACHTERBAK AL VOL IS.
8. VOLGENS HET WOORDENBOEK KUN JE OOK OVER LIJKKIST SPREKEN ALS JE GRAFKIST BEDOELT.
9. OP DIE PLEK LIGGEN SOMS BRAMEN EN BESSEN.
10. HIJ HEEFT TE WEINIG TIJD OM ZIJN CONDITIE WEER OP PIJL TE KRIJGEN.
11. DAT VOORWERP OP DE KAST LIJKT OP EEN MUILKORF VOOR EEN HOND.
12. VOORZICHTIG BETAST HIJ MET ZIJN VINGERS HET WEB EN VOELT HET PLAKKEN.
13. OP DIT MOMENT BEVINDEN ZE ZICH IN EEN BALZAAL EN DANSEN.
14. VANDAAG SCHRIJFT HIJ EEN WERKSTUK OVER DE KERNBOM EN DE GEVOLGEN.
15. IK VRAAG ME AF OF ZIJ IETS WETEN VAN DE KIEZERS DIE NIET ZIJN GEKOMEN.
16. JE KUNT HET NIET MAKEN OM DE PATIËNT TE LATEN WACHTEN.
17. ZIJ WIL DIE KWESTIE GRAAG BESPREKEN MET DE PAUS IN EEN RUSTIGE OMGEVING.
18. NORMAAL HEEFT HIJ NOOIT LAST VAN KOORTS ALS HIJ ZIEK IS.
19. WAT HEN WEL OPVIEL WAS DAT ER VEEL KALKAANSLAG OP ZAT.
20. HET PRAATJE IN DIE ZAAL GAAT OVER NOODHULP AAN PAKISTAN.
21. VOLGENS HEN HEEFT HET TOCH GEEN ZIN OM DE INVALLER TE BELASTEN.
22. DE POSTERS MAKEN RECLAME VOOR EEN CONGRES DAT IN AUGUSTUS PLAATSVINDT.
23. HET IS NIET AARDIG VAN HET MEISJE DAT ZIJ GEEN PASFOTO WIL GEVEN.
24. DROMEN KUNNEN GAAN OVER EEN BOTSING WAARBIJ VEEL MENSEN OMKOMEN.
25. OP DIE OMSLAG STAAT EEN PLAATJE VAN EEN BROMMER MET EEN JONGEN EROP.
26. HET LIJKT MIJ NIET NODIG OM EEN CAMERA TE KOPEN VOOR DE CURSUS.
27. HET MEISJE MERKT NIET DAT ZIJ MET HAAR PICKNICK BEESTJES AANTREKT.
28. ZIJ HOPEN DAT HET WAAR IS DAT DE HEMEL BESTAAT EN MOOI IS.
29. ZIJ WILLEN NIET DAT DE KLANTEN DE ROTZOOI ZIEN.
30. IN HET VERHAAL WORDT EEN GEBEURTENIS BESCHREVEN WAARIN MUISJES KAAS ZOEKEN.
31. DIE KINDEREN LUISTEREN GRAAG NAAR VERHALEN OVER EENHOORNS EN ELFJES.
32. IK HEB ECHT GEEN IDEE WAAROM DE FILMROL NAAR HEM GING.
33. NORMAAL GEBEURT HET NOOIT DAT ZIJN KIEZEN PIJN DOEN.
34. DE ZOON DIE BIJ ZIJN MOEDER INWOONT HEEFT EEN BULT DIE ONTSTOKEN IS.
35. HET GEBEURT NIET VAAK DAT MEN HIER KAASSAUS BIJ KRIJGT.
36. IN DE KELDER LIGGEN VEEL SCHILDERIJEN DIE STOFFIG ZIJN.
37. NA LANG NADENKEN KIEST ZE VOOR DE BADMAT MET STREPEN.
38. DE HANDELAAR PAKT DE DOOS MET PIEPSCHUIM OM WEG TE GOOIEN.
39. DIE KOOPMANNEN PAKKEN DE KRATTEN MET NOGA OM TE VERKOPEN.
40. DE VROUW IS HAASTIG OP ZOEK NAAR LAVENDEL VOOR IN DE TUIN.
41. GELUKKIG HEBBEN DIE MENSEN BIJNA ALLE INKTVLEKKEN ERUIT GEKREGEN.
42. VOORZICHTIG RAAKT HET MEISJE DE NAGELS AAN DIE GELAKT ZIJN.
43. OP DE TENTOONSTELLING ZIET HIJ FOTO'S VAN PASPOPPEN VAN VROEGER.

44. OP DE TEKENING IN HET BOEK STAAN ELANDEN MET JONGEN.
45. HIJ VINDT HET BELANGRIJK DAT DE WINKEL DE NAAM KRIJGT VAN ZIJN VADER.
46. DIE GROEP MENSEN IS IN GESPREK OVER DE VLUCHT VAN DE CRIMINELEN.
47. HIJ ZEGT DAT HET MISSCHIEN MOGELIJK IS OM DE HAL TE VERGROTEN.
48. WAT DE VREEMDE MAN PROBEERT TE BESCHRIJVEN ZIJN DE HENDELS VAN DE MACHINE.
49. DE SPRAAKZAME VROUWEN WILLEN IETS VERTELLEN OVER DE BIJBEL EN HUN GELOOF.
50. DE VROUW HEEFT GEHOORD OVER KLOMPEN MET BLOEMMOTIEF.
51. IN DE KLAS SCHRIJFT HIJ EEN OPSTEL OVER EEN TREIN EN ANDERE VERVOERMIDDELEN.
52. DE GROEP HEEFT HET OVER GIFGAS DAT VRIJ KAN KOMEN.
53. VOL ONGELOOF KIJKT HET KIND NAAR DE GRATEN VAN DE VIS.
54. DE MENSEN ZIJN ONDER DE INDRUK VAN DE DISCO EN DE FEESTGANGERS.
55. IN DE GROEP HEBBEN ZE HET OVER AARDOLIE EN AARDGAS.
56. SOMMIGE MENSEN KIJKEN AANDACHTIG NAAR DE RENPAARDEN DIE VOORBIJ KOMEN.
57. DE VADER VRAAGT HEM NAAR VERSCHILLENDE SOORTEN KORAAL EN KRIJGT UITLEG.
58. HET KIND HOUDT EEN SPREEKBEURT OVER BOMEN IN HET TROPISCH REGENWOUD.
59. IN DIE ZAAL WORDT EEN VOORLICHTING GEGEVEN OVER HET REDDINGSWERK BIJ RAMPEN.
60. IN DE SUPERMARKT VINDT MOEDER GOEDE PEULEN VOOR HET ETEN.
61. AAN DE TELEFOON SPREKEN ZIJ OVER EEN BEDRIJF IN EUROPA.
62. DE BABY KIJKT UITERST GEFASCINEERD NAAR DE ESPRESSO OP TAFEL.
63. DIE MIDDAG PRESENTEERT DE COMMISSIE EEN RAPPORT OVER EEN PROCES DAT LANG HEEFT GEDUURD.
64. OMDAT HET NIET ANDERS KAN PROBEERT HIJ MET FOLIE HET GAT TE DICHTEN.
65. HET WAS OOK TE MOOI OM WAAR TE ZIJN DAT DE GASFLES NOG VOL WAS.
66. IN DE WINKEL WILDE DE VROUW MEER WETEN OVER EEN COMPUTER DIE TE KOOP STOND.
67. IK DACHT DAT HET ONMOGELIJK WAS OM DE OFFERTE TE VERANDEREN.
68. HET VIEL HEN WEL OP DAT DE OGEN SCHEEF STONDEN.
69. AFWEZIG STAARDE HET MEISJE NAAR EEN LEESBRIL OP TAFEL.
70. ZIJ VONDEN HET MOEILIJK MAAR KOZEN TOCH VOOR EEN KOELKAST MET VRIESVAK.
71. DE KINDEREN LEERDEN DIE DAG DAT EEN LIFT AAN STAALKABELS HANGT.
72. DE MAN SCHREEF IN HET VERSLAG DAT DE HARTKWAAL ERGER WERD.
73. DIE MENSEN SCHROKKEN VAN DE OPHAALBRUG DIE OPEENS OMHOOG GING.
74. WANHOPIG WENDDEN DIE MENSEN ZICH TOT EEN PAAR OBERS OM TE BESTELLEN.
75. HOEWEL DIE MAN NIET VEEL GEEFT OM DE ARMEN DONEERDE HIJ TOCH GELD.
76. HIJ VOND HET NIET ERG OM DE KAPPER THUIS TE BRENGEN.
77. IN GEDACHTEN VERZONKEN PAKTE HIJ DE SUIKER EN VULDE HET SCHAALTJE.
78. DE DOKTER KEEK GOED NAAR ZIJN OKSELS MAAR ZAG NIETS VREEMDS.
79. DIE MENSEN VONDEN HET ERG INTERESSANT DAT DE ACHTBAAN WERD AFGEBROKEN.
80. IN DE HAAST VERGAT ZIJ DE BODEM SCHOON TE MAKEN.
81. HET VIEL NIET MEE OM ALLE BRIEVEN GRONDIG TE LEZEN.
82. HIJ ZOEKT IN DE SCHAPPEN NAAR GEITENKAAS MAAR VINDT HET NIET.
83. NADAT ZIJ HADDEN RONDGEKEKEN VONDEN ZIJ MOOIE BLOEMEN VOOR OP TAFEL.
84. VLUCHTIG LIET HIJ ZIJN BLIK GAAN OVER DE BENEN VAN HET MODEL.
85. OP DE TELEVISIE ZAGEN ZIJ EEN PROGRAMMA OVER EEN CASINO MET EEN GROOT DAKTERRAS.
86. HET HEEFT VEEL TIJD EN INSPANNING GEKOST MAAR DE TRIBUNE IS NU EINDELIJK AF.
87. HIJ VERSTOND HAAR NIET GOED TOEN ZE HET HAD OVER DE HALFGOD UIT DE MYTHE.
88. NA LANG ZOEKEN IN DE SCHUUR VOND HIJ EEN DOBBER DIE HIJ MEENAM.
89. WAT IN DEZE WINKEL VEEL VERKOCHT WORDT IS DE KALENDER MET DIEREN.
90. NADAT HIJ VERSCHEIDENE WINKELS WAS AFGEWEEST KOCHT HIJ EEN DIENBLAD VOOR ZIJN MOEDER.
91. HIJ DACHT NET OP TIJD AAN DE DIENST DIE HIJ MOEST DRAAIEN.

92. GECONCENTREERD TUURDE DE MAN NAAR DE REKENING DIE NIET KLOPTE.
93. HIJ WILDE MET HEM PRATEN OVER DE TOEKOMST VAN DE STICHTING.
94. DE MAN WERD EVEN AFGELEID DOOR DE BLIKSEM EN VERONGELUKTE.
95. HIJ SCHREEF EEN UITEENZETTING OVER HET BEGRIP RECHTVAARDIGHEID VOOR IEDEREEN.
96. ZE WIST NIET WAT TE DOEN MET EEN PASPOORT DAT IN HET WATER WAS GEVALLEN.
97. HET KOMT BEST VAAK VOOR DAT ER EEN TOEGIFT WORDT GEGEVEN.
98. HELAAS KON DIE JONGEN ONS NIET VEEL VERTELLEN OVER DE POST DIE WAS ZOEKGERAAKT.
99. OP HET PAPIER STOND EEN TERMIJN VOORGESTELD DIE ONREDELIJK WAS.
100. TUSSEN ALLE ROMMEL VOND HIJ EEN PIJL MET SCHERPE PUNT.
101. ZIJ SCHROK TOEN ZIJ HOORDE DAT DE VINGERS MOESTEN WORDEN GEAMPUTEERD.
102. TIJDENS DE LUNCH SPRAKEN DE VRIENDEN OVER DE FINALIST VAN HET PROGRAMMA.
103. VOOR DIE VROUW WAS HET DE EERSTE KEER DAT ZIJ EEN KATER HAD NA HET UITGAAN.
104. DIE MEVROUW IN DE VORIGE WINKEL NOEMDE HET EEN MAILLOT EN GEEN LEGGING.
105. DIE PERSONEN VONDEN DAT HET LEEK ALSOF DE BOCHT SCHERPER WAS GEWORDEN.
106. TIJDENS DE BIJEENKOMST LEGDE ZIJ HET STUK VOOR AAN EEN DIRIGENT DIE HET BEKEEK.
107. TIJDENS DE CURSUS MAAKTE HIJ EEN SCHETS VAN EEN REGENTON EN KLEURDE HET IN.
108. TIJDENS HET WANDELEN VERTELDEN ZIJ DAT EEN ONGELUK HEM FATAAL WERD.

Syntactic condition (syntactic correct/syntactic incorrect)

1. DE UIT NEDERLAND AFKOMSTIGE VOETBALLER VERTOEFT/VERTOEVEN NU IN SPANJE.
2. HET SLANKE MODEL OP HET PODIUM GLIMLACHT/GLIMLACHEN NAAR DE FOTOGRAAF.
3. DIE DAPPERE EN EDELE RIDDER SPRINGT/SPRINGEN OP ZIJN PAARD EN GALOPPEERT WEG.
4. ALHOEWEL DAT KLEINE MEISJE MEESTAL HEIMWEE HEEFT/HEBBEN GAAT ZE TOCH BIJ OMA LOGEREN.
5. DE VROME DOMINEE VAN DIE PROTESTANTSE KERK PREEKT/PREKEN EN VERHEFT DAARBIJ ZIJN STEM.
6. DE BEELDSCHONE ASSISTENTE VAN DE GOOCHELAAR STAPT/STAPPEN IN DE KIST EN VERDWIJNT IN HET NIETS.
7. DE GROOTVADER DIE ZIJN KLEINKIND VOOR HET SLAPEN EEN VERHAAL VERTELT/VERTELLEN HEEFT VEEL FANTASIE.
8. DE KILLE MOORDENAAR DIE OVER ZIJN LAATSTE SLACHTOFFER DROOMT/DROMEN HEEFT EEN GLIMLACH OP ZIJN GEZICHT.
9. DE BETROKKEN MANAGER DIE ZELF MET DE BETREFFENDE MEDEWERKER SPREEKT/SPREKEN BELOOFT SNEL VERBETERING.
10. DE NIEUWE JUF VAN GROEP ZEVEN IS/ZIJN STRENG MAAR ZEKER WEL RECHTVAARDIG.
11. DE ENTHOUSIASTE DIRECTEUR VAN HET NIEUWE BEDRIJF BELT/BELLEN MET POTENTIËLE KLANTEN.
12. DE AARDIGE ZUSTER DIE AL LANG IN HET ZIEKENHUIS WERKT/WERKEN PRIKT IN ZIJN ADER.
13. DE OUDE MAN DIE 'S OCHTENDS GRAAG MET ZIJN HOND WANDELT/WANDELEN STAAT AL VROEG OP.
14. HET IJVERIGE PERSONEEL VAN DE BAKKER SNIJDT/SNIJDEN HET BROOD EN DOET HET IN ZAKKEN.
15. HET ONLANGS GETROUWDE JONGE KOPPEL AAST/AZEN OP DE GOEDKOPE WONING.
16. DE DOCHTER VAN DE WERKLOZE BEDELT/BEDELEN IN HET CENTRUM.
17. DE ZOON VAN DE DIRECTRICE BAALT/BALEN VAN ZIJN SLECHTE CIJFER.
18. DE GOEDE KENNIS VAN DE OVERLEDENE CONDOLEERT/CONDOLEREN DE ECHTGENOOT EN ZWIJGT.
19. DE JONGE EZEL VAN DE BOERIN BALKT/BALKEN EN SCHOPT HARD.
20. DE VRIEND VAN DAT MEISJE PINT/PINNEN EN VERTREKT.
21. DE HULP VAN DIE MEVROUW STOFT/STOFFEN EN ZUIGT DE KAMER.
22. DE KLEINZOON VAN DE ACTRICE DEBUTEERT/DEBUTEREN IN DIE FILM EN IS GOED.
23. DE SCHOONMAAKSTER VAN HAAR OMA DWEILT/DWEILEN DE VLOER EN ZINGT ONDERTUSSEN.
24. DE TUINMAN VAN DE BEJAARDE VROUW HARKT/HARKEN EN SCHOFFELT LANGZAAM.
25. DE GESTOORDE MAN DIE DE BANKIER GIJZELT/GIJZELEN WIL VEEL LOSGELD.
26. DE MEDEWERKER DIE HET GEZIN HERENIGT/HERENIGEN HEEFT VEEL MOEITE GEDAAN.
27. DE ARTS DIE DE PATIËNT REANIMEERT/REANIMEREN KRIJGT GEEN HULP.
28. HET MEISJE DAT BIJ HAAR BUURMAN AFKIJKT/AFKIJKEN DOET DIT ONGEMERKT.

29. DIE BLAUWE VULPEN MET DE RODE DOP SCHRIJFT/SCHRIJVEN HELEMAAL NIET FIJN.
30. DE SMERIGE OLIE DIE UIT DE KAPOTTE TANKER LEKT/LEKKEN VERVUILT HET STRAND.
31. DE WEKKER IN DE SLAAPKAMER GAAT/GAAN AF EN WEKT DE MENSEN.
32. ZIJN TIJDELIJKE CONTRACT DAT DEZE MAAND AFLOOPT/AFLOPEN KAN NIET WORDEN VERLENGD.
33. HET WITTE BORD VAN PORSELEIN BREEKT/BREKEN TIJDENS DE AFWAS.
34. DE GROTE TRUCK DIE DAAR VAN DE VEERBOOT RIJDT/RIJDEN IS VAN MIJN VADER.
35. DE ROZE SHAMPOO IN DIE FLES RUIKT/RUIKEN NAAR LAVENDEL.
36. HET OPGEREKTE ELASTIEK OM DE BROODTROMMEL KNAPT/KNAPPEN EN BELANDT OP DE GROND.
37. DE KRACHTIGE ORKAAN DIE TEGEN DE MIDDAG HET EILAND BEREIKT/BEREIKEN ZAL WAARSCHIJNLIJK VEEL SCHADE AANRICHTEN.
38. HET DURE CADEAU DAT ECHTER NIET IN DE SMAAK VALT/VALLEN KAN GELUKKIG WORDEN GERUILD.
39. DE KLEINE WINKEL DIE VANWEGE HET NADERENDE FAILLISSEMENT SLUIT/SLUITEN DOET ALLES IN DE UITVERKOOP.
40. DIE MOOIE ROZENSTRUIK IN DE TUIN BLOEIT/BLOEIEN VOLOP EN TREKT BIJEN AAN.
41. DE NIEUWE LAMP DIE NOG STEEDS IN DE VERPAKKING ZIT/ZITTEN IS ERG BREEKBAAR.
42. DE GOEDKOOPSTE JURK VAN DIE COLLECTIE KOST/KOSTEN MAAR LIEFST TACHTIG EURO.
43. DE EERSTE LES IN HET WIJKCENTRUM BEGINT/BEGINNEN DIE OCHTEND OM ACHT UUR.
44. DIE KNOP OP HET DASHBORD ACTIVEERT/ACTIVEREN HET GROTE LICHT.
45. HET BEDRIJF IN DIE SECTOR DONEERT/DONEREN EEN GROOT BEDRAG.
46. DE SNEEUW OP DE WEG DOOIT/DOOIEN DOOR HET WARME WEER.
47. HET NIEUWE APPARAAT IN HET KANTOOR PRINT/PRINTEN HEEL ERG SNEL.
48. DE CRÈME UIT DIE TUBE VERKOELT/VERKOELEN DE HUID EN IRRITEERT NIET.
49. HET DUNNE PAPIER VAN DIE STAPEL KREUKT/KREUKEN SNEL EN VERKLEURT.
50. HET ZWARE ROTSBLOK VAN TWEE TON PLONST/PLONZEN IN HET WATER EN ZINKT.
51. HET HELDERE KOUDE WATER IN DE VOLLE EMMER GUTST/GUTSEN OVER DE RAND EN VERDAMPT.
52. HET LUIK DAT DOOR DE WIND DICHTVALT/DICHTVALLEN GAAT MOEILIJK OPEN.
53. DE RIJST DIE IN DE PAN AANBRANDT/AANBRANDEN IS NIET MEER EETBAAR.
54. DE SPECIAAL VOOR HET FEEST OVERGEKOMEN GASTEN BLIJVEN/BLIJFT OOK NOG HET HELE WEEKEND.
55. DE BLIJE TRAINERS VAN DE WINNENDE TURNSTERS VIEREN/VIERT DE OVERWINNING MEE EN ZIJN ERG TEVREDEN.
56. HOEWEL DIE LUIE JONGENS EIGENLIJK NIET GRAAG FIETSEN/FIETST DOEN ZE ER NIET MOEILIJK OVER.
57. DE BIOLOGISCHE MOEDERS VAN DE GEADOPTEERDE KINDEREN WONEN/WOONT IN BOLIVIA EN HEBBEN NOG STEEDS VERDRIET.
58. DE OUDERS VAN DIE BRUTALE EN ONGEHOORZAME KINDEREN WETEN/WEET NIETS VAN OPVOEDEN AF.
59. DE VELE TOESCHOUWERS DIE AANDACHTIG NAAR DE ACTEURS KIJKEN/KIJKT VERMAKEN ZICH PRIMA.
60. DE HOGE DIPLOMATEN DIE IN HET GEHEIM VOOR DE AMERIKANEN SPIONEREN/SPIONEERT MOETEN MOSKOU VERLATEN.
61. DE STOERE BOUWVAKKERS DIE GRAAG NAAR DE JONGE MEISJES FLUITEN/FLUIT KRIJGEN GEEN RESPONS.
62. DE VADERS DIE SIERLIJK MET HUN JONGSTE DOCHTERS DANSEN/DANST HEBBEN ER VEEL PLEZIER IN.
63. DE RECHERCHEURS DIE EEN LANGE TIJD MET DE ARRESTANTEN PRATEN/PRAAT KOMEN NIET VEEL VERDER.
64. DE VELE HONDERDEN BEZOEKERS VAN DE FEESTELIJKE FESTIVITEITEN KOMEN/KOMT VOORAL UIT DE OMGEVING.
65. DE BEROEMDE ARTIESTEN DIE GRAAG VOOR HUN UITZINNIGE FANS ZINGEN/ZINGT STAAN ALWEER KLAAR OP HET PODIUM.
66. DE ONVERMOEIBARE REDDINGSWERKERS DIE AL ENKELE DAGEN NAAR OVERLEVENDEN ZOEKEN/ZOEKT ZIJN HIERVOOR SPECIAAL OPGELEID.
67. DE ZWARTE GEITEN VAN DIE TWEE HERDERS GRAZEN/GRAAST IN DE BERM EN STEKEN DE WEG OVER.
68. DE WAAKSE HONDEN VAN ONZE BUREN BLAFFEN/BLAFT ALTIJD HARD NAAR ONSCHULDIGE PASSANTEN.
69. DE MOEDERS VAN DE BABY'S PRAKKEN/PRAKT HET ETEN FIJN.
70. ZOWEL DE KINDEREN ALS DE VOLWASSENEN AAIEN/AAIT HET JONGE DIER.
71. DE VOOGDEN VAN DE KLEINE KINDEREN BEHEREN/BEHEERT AL HET GELD.
72. DE VRIENDEN VAN DE VERPLEEGSTERS BROUWEN/BROUWT HUN EIGEN DRANK.
73. DE MEISJES UIT DIE GEZINNEN FIGUREREN/FIGUREERT IN DE FILM.

74. DIE MANNEN EN HUN VROUWEN POKEREN/POKERT EN ZIJN LUIDRUCHTIG.
75. DE EIGENAREN VAN DE PAARDEN VERVERSEN/VERVERST HET HOOI EN RIJDEN WEG.
76. DE ZEER GEVAARLIJKE SOMALISCHE PIRATEN KAPEN/KAAPT HET SCHIP EN VAREN WEG.
77. DE DEFTIGE ECHTGENOTEN VAN DE AMBASSADEURS POEDEREN/POEDERT HUN NEUS EN KLETSEN VOLOP.
78. DE DOOR DE STUDENTEN UITGENODIGDE GASTEN SMULLEN/SMULT VAN HET ETEN EN GENIETEN.
79. BIJNA ALLE LEERLINGEN VAN DIE ONAARDIGE DOCENTEN SPIJBELEN/SPIJBELT EN SCOREN SLECHT.
80. DIE LEEUWINNEN DIE DE PROOIEN DOODBIJTEN/DOODBIJT ZIJN NOG JONG.
81. DE JONGENS DIE MET HUN VRIENDJES KNIKKEREN/KNIKKERT HEBBEN VEEL LOL.
82. DE MET ROOD FLUWELEN STOF BEKLEDE STOELEN STAAN/STAAT ACHTER IN DE WINKEL.
83. DE GROTE WIEKEN VAN DE WINDMOLENS DRAAIEN/DRAAIT HARD IN HET ROND.
84. DIE OUDE EN VERSLETEN BLAUWE SLOFFEN MOETEN/MOET NU ECHT WORDEN WEGGEGOOID.
85. DE ZWARE STENEN DIE VAN DE HELLINGEN NAAR BENEDEN ROLLEN/ROLT BESCHADIGEN DE VOERTUIGEN.
86. DIE TROPISCHE PLANTEN MET GROTE ROZE BLOEMEN GROEIEN/GROEIT SNEL DOOR HET VELE WATER.
87. DE SCHONE KLEREN EN HANDDOEKEN HANGEN/HANGT AAN DE WASLIJN OM TE DROGEN.
88. DE GROTE FABRIEKEN DIE ILLEGAAL IN DE RIVIEREN LOZEN/LOOST ONTVANGEN EEN HOGE BOETE.
89. DE ZWARE DEUREN VAN DIE GOED BEVEILIGDE KLUIZEN KUNNEN/KAN OPEN ALS DAT NODIG WAS.
90. DE AUTO'S DIE NIET VOOR DE RODE STOPLICHTEN STOPPEN/STOPT WORDEN VERDEROP AANGEHOUDEN.
91. DE HOUTEN SLEETJES OP DE STEILE HELLINGEN GLIJDEN/GLIJDT NAAR BENEDEN EN MAKEN VEEL VAART.
92. DE VERSCHILLEND GEKLEURDE BORDJES AAN DE MUREN WIJZEN/WIJST DE WEG EN LICHTEN OP IN HET DONKER.
93. DE KRACHTIGE BOMMEN DIE PLOTSELING IN DE GEBOUWEN ONTPLOFFEN/ONTPLOFT RICHTEN VEEL SCHADE AAN.
94. DE WOESTE GOLVEN DIE OVER DE HOGE DUINEN SLAAN/SLAAT MAKEN DE BADGASTEN BANG.
95. DE SCHITTERENDE MET GOUD EN ZILVER AFGEZETTE JUWELEN LIGGEN/LIGT IN DE VITRINE EN WORDEN BEWAAKT.
96. DE WINKELS MET DIE DURE MERKEN PROMOTEN/PROMOOT EEN VERNIEUWD PRODUCT.
97. DE WEGEN IN DIE DORPJES VERSMALLEN/VERSMALT SOMS HEEL PLOTSELING.
98. DE RITSEN VAN DIE JASSEN ROESTEN/ROEST VAN HET WATER.
99. DE VOORSTELLEN IN DIE BRIEVEN DRUISEN/DRUIST TEGEN ZIJN NORMEN IN.
100. DEZE OUDE HUIZEN MET VAN DIE GROTE KIEREN TOCHTEN/TOCHT EN KRAKEN ONTZETTEND.
101. BIJNA ALLE ZOMEN VAN DIE OUDE VESTEN RAFELEN/RAFELT EN ZIJN VIES.
102. DE KLEINE BOOTJES MET WITTE ZEILEN DOBBEREN/DOBBERT OP HET WATER EN DRIJVEN WEG.
103. DE VELE KAARSEN OP DE OMRINGENDE TAFELTJES FLAKKEREN/FLAKKERT EN GAAN DAN UIT.
104. DIE RODE BULTJES OP ZIJN BEIDE HANDEN JEUKEN/JEUKT EN GAAN NIET WEG.
105. DE BALLEN DIE OP DE TEGELS STUITEREN/STUITERT ZIJN ERG HARD.
106. DE MOLENS DIE DE KORRELS MALEN/MAALT ZIJN VAN VROEGER.
107. DE SCHEPEN DIE IN DE HAVENS VASTLIGGEN/VASTLIGT KUNNEN NIET WEG.
108. DE TELEFOONS DIE DOOR DE ACCU’S OPLADEN/OPLAADT ZIJN BIJNA VOL.

Plausibility condition (plausible/mildly implausible/deeply implausible)

1. VASTE LASTEN ZOALS GAS, WATER EN LICHT/VERWARMING/ROOKWORST MOETEN OOK BETAALD WORDEN.
2. ALLE DELEN VAN HET GEZICHT ZOALS DE OREN, NEUS EN MOND/SPROETEN/BAL VERSCHILLEN PER PERSOON.
3. LICHAAMSDELEN ZOALS EEN ARM, NEK EN TEEN/HAAR/TELESCOOP HEBBEN ELK HUN EIGEN FUNCTIE.
4. EMOTIES ZOALS VREUGDE, VERDRIET EN ANGST/LACH/TOREN ZORGEN VOOR LICHAMELIJKE VERANDERINGEN.
5. HET ROKEN VAN EEN SIGAAR, PIJP EN SIGARET/DRUGS/KAPSTOK IS VERSLAVEND.
6. HUISDIEREN ZOALS KONIJNEN, HONDEN EN KATTEN/ZWIJNEN/MUGGEN MOETEN GOED VERZORGD WORDEN.
7. DE SEIZOENEN ZOALS ZOMER, HERFST EN WINTER/VOORJAAR/KLAPPER WISSELEN ELKAAR AF.
8. DAT SERVIES BESTAANDE UIT ONDER ANDERE GLAZEN, KOMMEN EN BORDEN/PANNEN/TRAPPEN IS TWAALFDELIG.
9. BIJBELSE FIGUREN ZOALS JOZEF, MARIA EN JEZUS/KAÏN/LINDA STAAN OP VEEL AFBEELDINGEN.
10. VOOR HET OPENBAAR VERVOER ZOALS DE METRO, TRAM EN BUS/TAXI/GRENS MOET JE KAARTJES KOPEN.

11. ZUIVELPRODUCTEN ZOALS YOGHURT, KAAS EN MELK/EI/BAK LIGGEN IN DE KOELING.
12. MEUBELS WAARONDER EEN BANK, BED EN KAST/LAMP/RADAR VIND JE IN DE WOONWINKEL.
13. DIE BEELDEN VAN KLEI, BRONS EN KOPER/ZAND/LOGO STAAN HIER TENTOONGESTELD.
14. TALEN OP DE MIDDELBARE SCHOOL ZOALS NEDERLANDS, DUITS EN FRANS/FRIES/CADEAU KRIJGEN VEEL AANDACHT.
15. GEESTELIJKEN ZOALS PRIESTERS, DOMINEES EN PASTOORS/DEKENS/BEREN WIJDEN ZICH AAN HUN RELIGIE.
16. MUZIEK OP ONDER ANDERE CASSETTEBANDJES, CD'S EN PLATEN/RADIO/LUCHTKUSSEN ZORGT VOOR SFEER.
17. BEKENDE HOOFDSTEDEN ZOALS AMSTERDAM, PARIJS EN ROME/ZWOLLE/BRIEVENBUS HEBBEN VEEL INWONERS.
18. VERSCHEIDENE RELIGIES ZOALS HINDOEÏSME, ISLAM EN CHRISTENDOM/KATHOLIEK/GRONDWET KENNEN HET BEGRIP NAASTENLIEFDE.
19. DIEREN OP DIE BOERDERIJ ZOALS KIPPEN, VARKENS EN KOEIEN/CAVIA'S/APEN HEBBEN WEINIG RUIMTE.
20. KLEDING ZOALS TRUIEN, BROEKEN EN ROKKEN/HOEDEN/SLUIZEN LIGT IN DE KLERENKAST.
21. WAPENS ZOALS EEN ZWAARD, MES EN PISTOOL/BOOG/VUILNISZAK ZIJN ERG GEVAARLIJK.
22. DIE CAMPING MET ONDER ANDERE CAMPERS, CARAVANS EN TENTEN/ZWEMBADEN/GROTTEN IS AL HELEMAAL VOL.
23. BADKAMERS MET ONDER ANDERE EEN DOUCHE, TOILET EN BAD/BIDET/MEMO VIND JE IN DIT HOTEL.
24. ONGEDIERTE ZOALS MUIZEN, KAKKERLAKKEN EN RATTEN/SLANGEN/HONDEN MOET METEEN BESTREDEN WORDEN.
25. INGREDIËNTEN VOOR EEN APPELTAART ZOALS BLOEM, ROZIJNEN EN BOTER/SLAGROOM/PAPRIKA KOOPT HIJ IN DE SUPERMARKT.
26. CIRCUSDIEREN ZOALS TIJGERS, OLIFANTEN EN LEEUWEN/ZEBRA'S/KIPPEN MOETEN GOED VERZORGD WORDEN.
27. BEROEPEN IN DE FILMWERELD ZOALS PRODUCENT, REGISSEUR EN ACTEUR/MODEL/BIEB WORDEN VAAK GOED BETAALD.
28. OPPERVLAKTEWATER ZOALS EEN SLOOT, RIVIER EN BEEK/WATERVAL/LETTER KAN VERVUILD WORDEN.
29. SPEELKAARTEN WAARONDER SCHOPPEN, HARTEN EN RUITEN/KONINGEN/SCHUTTINGEN GEBRUIK JE BIJ BRIDGEN.
30. TIJDENS MAALTIJDEN ZOALS ONTBIJT, AVONDETEN EN LUNCH/DESSERT/BOODSCHAP EET MEN VAAK VEEL.
31. PLANETEN ZOALS SATURNUS, MARS EN VENUS/ZON/NUMMER ZIJN NAGENOEG ROND.
32. GEDURENDE LEVENSFASEN VAN DE MENS ZOALS BABY, PEUTER EN KLEUTER/KINDERTIJD/GEDRAG VINDT ONTWIKKELING PLAATS.
33. ORGANEN ZOALS HART, LONGEN EN NIEREN/KLIEREN/KACHEL KUNNEN OOK WORDEN AANGETAST.
34. VOORSTELLINGEN IN DE SCHOUWBURG ZOALS CABARET, TONEELSTUK EN OPERA/FILM/PYJAMA ZIJN SNEL UITVERKOCHT.
35. VERSCHILLENDE LANDEN IN EUROPA ZOALS BELGIË, DUITSLAND EN GRIEKENLAND/TURKIJE/DIPLOMA HEBBEN ONDERLINGE AFSPRAKEN.
36. HAAR WERKDAGEN WAARONDER MAANDAG, DINSDAG EN WOENSDAG/ZONDAG/ROLSTOEL GAAN SNEL VOORBIJ.
37. PROVINCIES ZOALS DRENTHE, LIMBURG EN ZEELAND/VLAANDEREN/PAAL WERKEN ONDERLING SAMEN.
38. BRANDSTOFFEN VOOR EEN AUTO ZOALS DIESEL, GAS EN BENZINE/WATERSTOF/NERF WORDEN STEEDS DUURDER.
39. CONTINENTEN ZOALS AFRIKA, EUROPA EN AZIË/NOORDPOOL/MARKTKRAAM VERPLAATSEN ZICH VOORTDUREND.
40. VERF IN ALLERLEI KLEUREN WAARONDER ROOD, GEEL EN BLAUW/PASTEL/POOT VINDT HIJ ERG MOOI .
41. DE JACHT OP ONDER ANDERE EVERZWIJNEN, KONIJNEN EN VOSSEN/OSSEN/MIEREN IS WEER GEOPEND.
42. DEZE UITRUSTING VOOR DE WINTERSPORT MET EEN SKIBRIL, JAS EN MUTS/ZONNEBRAND/KLOOSTER ZIET ER MOOI UIT.
43. SCHOENEN ZOALS PUMPS, LAARZEN EN SANDALEN/SCHAATSEN/VAZEN ZIJN ER IN ALLERLEI MERKEN.
44. EEN ENGELS ONTBIJT MET WORSTJES, EIEREN EN SPEK/JAM/BRADERIE GAAT ER WEL IN.
45. DELEN VAN EEN HAND ZOALS EEN DUIM, WIJSVINGER EN PINK/BOT/TOETS ZIJN ONDERLING VERBONDEN.
46. BEKENDE WETENSCHAPPERS ZOALS EINSTEIN, NEWTON EN DARWIN/POPPER/JANSEN WAREN ERG VINDINGRIJK.
47. KRUIDEN ZOALS BIESLOOK, BASILICUM EN TIJM/MOSTERD/RAPPORT WORDEN GEBRUIKT TIJDENS HET KOKEN.
48. VISSEN ZOALS EEN SNOEK, BAARS EN PALING/HAAI/HERT ZIJN GEWERVELDE DIEREN.
49. NOTEN ZOALS EEN PINDA, HAZELNOOT EN AMANDEL/KOKOSNOOT/PLEIN KUNNEN ALLERGISCHE REACTIES VEROORZAKEN.
50. DE VERTREKKEN IN DAT HUIS ZOALS DE WOONKAMER, SLAAPKAMER EN EETKAMER/GANG/WIELDOP HEBBEN EEN EIGEN STIJL.
51. EEN RIDDERUITRUSTING BESTAANDE UIT ONDER ANDERE EEN HARNAS, SCHILD EN LANS/PAARD/GELUID STAAT TENTOONGESTELD.
52. SCHOENEN BESTAANDE UIT ONDER ANDERE EEN ZOOL, HAK EN VETERS/LIP/TEST BESCHERMEN JE VOETEN.
53. HET VLEES VAN DE SLAGER ZOALS GEHAKT, SAUCIJZEN EN BIEFSTUK/TONG/BALKON LIGT IN DE VITRINE.

54. DRUGS ZOALS COCAÏNE, MARIHUANA EN HASJ/ALCOHOL/LUCHT HEBBEN EEN DROGERENDE WERKING.
55. ZEEDIEREN ZOALS GARNALEN, INKTVIS EN KREEFT/ANEMOON/HAMSTER WORDEN HIER VERS BEREID.
56. AAN WOONRUIMTEN ZOALS EEN HUIS, FLAT EN BUNGALOW/IGLO/MONITOR IS SOMS EEN TEKORT.
57. KONINKLIJKE HOOGHEDEN ALS MAXIMA, WILLEM-ALEXANDER EN BEATRIX/CHARLES/KALKOEN GAAN SOMS OP STAATSBEZOEK.
58. GROENTEN ZOALS SLA, TOMATEN EN KOMKOMMER/AARDAPPELS/WOESTIJN ZIJN GEZOND.
59. BOMEN ZOALS EEN SPAR, EIK EN BERK/PALM/SCHETSBOEK PRODUCEREN ZUURSTOF.
60. SOORTEN WEERTYPEN ZOALS REGEN, ZON EN HAGEL/ORKAAN/POSTER KUNNEN GOED WORDEN VOORSPELD.
61. INSECTEN ZOALS KEVERS, MUGGEN EN WESPEN/LARVEN/SCHAPEN LEVEN IN HET NATUURGEBIED.
62. ZWEMKLEDING ZOALS EEN BADPAK, ZWEMBROEK EN BIKINI/FLIPPER/SNELWEG HEEFT VELE KLEUREN.
63. ONDERGOED ZOALS EEN BEHA, BOXERSHORT EN SLIP/PANTY/PARKET DRAAG JE ONDER JE KLEREN.
64. TOETJES ZOALS VLA, YOGHURT EN PUDDING/KOFFIE/BEHANG SLUITEN EEN MAALTIJD AF.
65. HET OOG BESTAANDE UIT ONDER ANDERE EEN PUPIL, IRIS EN NETVLIES/WENKBRAUW/STICKER IS ERG GEVOELIG.
66. GRAANSOORTEN ZOALS HAVER, GERST EN ROGGE/GIST/PLANK WORDEN VEEL VERBOUWD.
67. OOK VOGELS ZOALS DE EKSTER, KRAAI EN SPREEUW/KAKETOE/HORZEL HEBBEN VOLDOENDE VOCHT NODIG.
68. PSYCHISCHE STOORNISSEN ZOALS DEMENTIE, SCHIZOFRENIE EN DEPRESSIE/AFASIE/DOP KOMEN VAAK VOOR.
69. EENHEDEN ZOALS LITER, METER EN KILOGRAM/HOOGTE/BRIGADE WORDEN GEBRUIKT BIJ METINGEN.
70. IN MIJNEN MET BIJVOORBEELD KOLEN, GOUD EN ERTS/STENEN/KNOPPEN WORDT HARD GEWERKT.
71. VERSCHILLENDE ARTSEN ZOALS EEN CARDIOLOOG, DERMATOLOOG EN NEUROLOOG/THERAPEUT/CLOWN WERKEN IN EEN ZIEKENHUIS.
72. SNOEPJES ZOALS LOLLIES, ZUURTJES EN DROPJES/KOEKJES/RIJLESSEN ZIJN ERG LEKKER.
73. CHEMISCHE ELEMENTEN ZOALS NATRIUM, KALIUM EN CALCIUM/PLASTIC/BEL WORDEN DOOR SCHEIKUNDIGEN GEBRUIKT.
74. ETEN BIJ DE SNACKBAR ZOALS EEN FRIETJE, KROKET EN HAMBURGER/SALADE/ENVELOP VULT DE MAAG.
75. SCHEPEN ZOALS SLEEPBOTEN, VEERBOTEN EN DUIKBOTEN/KANO'S/RECEPTIES HEBBEN EEN BEMANNING NODIG.
76. SIERADEN ZOALS HORLOGES, KETTINGEN EN OORBELLEN/KRALEN/WONDEN WORDEN VEEL GEDRAGEN.
77. TENNISSLAGEN ZOALS DE FOREHAND, BACKHAND EN SERVICE/LOB/PILAAR VEREISEN EEN GOEDE TECHNIEK.
78. DIE ELEKTRONICAZAAK MET COMPUTERS, TELEVISIES EN PRINTERS/KOELBOXEN/FLESSEN MAAKT VEEL WINST.
79. DIE SPEELTUIN MET ONDER ANDERE EEN KLIMREK, SCHOMMEL EN ZANDBAK/PRULLENBAK/KAART WORDT DRUK BEZOCHT.
80. VOETBALTERMEN ZOALS HOEKSCHOP, BUITENSPEL EN STRAFSCHOP/VLAG/BLOEMPOT WORDEN VAAK GEBRUIKT.
81. ARTIKELEN BIJ DE DROGIST ZOALS PARFUM, CRÈME EN SHAMPOO/VOEDING/BIDONS STAAN OP DE SCHAPPEN.
82. BOTTEN VAN EEN SKELET ZOALS BORSTBEEN, SLEUTELBEEN EN SCHEENBEEN/POLS/KOOI BEVATTEN CALCIUM.
83. VERSCHILLENDE MENUGANGEN ZOALS VOORGERECHT, HOOFDGERECHT EN NAGERECHT/SOEP/PUNAISE STAAN OP DE KAART.
84. VERSCHILLENDE SOORTEN GLAZEN ZOALS EEN WIJNGLAS, THEEGLAS EN BIERGLAS/BEKER/STOPCONTACT STAAN OP EEN RIJ.
85. TUINGEREEDSCHAP ZOALS EEN HARK, GRASMAAIER EN SNOEISCHAAR/BIJL/VERDIEPING GEBRUIKT HIJ VEEL.
86. VERSCHILLENDE SOORTEN BEDDEN ZOALS EEN TWEEPERSOONSBED, TWIJFELAAR EN STAPELBED/WIEG/KROON STAAN IN DIE SHOWROOM.
87. DIEREN IN DE DIERENTUIN ZOALS TIJGERS, APEN EN GIRAFFEN/VLINDERS/POEDELS LEVEN BINNEN OMHEININGEN.
88. VOOR ZIEKTES ZOALS AIDS, MALARIA EN LEPRA/GRIEP/SNOER PROBEERT MEN MEDICIJNEN TE ONTWIKKELEN.
89. PRODUCTEN VOOR JE HAAR ZOALS HAARLAK, MOUSSE EN GEL/BORSTEL/KLOK STAAN IN HET LAATSTE GANGPAD.
90. ELKE MENSELIJKE ZANGSTEM ZOALS BAS, TENOR EN SOPRAAN/VROUWENSTEM/KORF HEEFT EEN BEPAALD BEREIK.
91. DIE BAND BESTAANDE UIT EEN ZANGER, DRUMMER EN GITARIST/VIOLIST/TUINMAN MAAKT MOOIE MUZIEK.
92. ARTIKELEN IN DE KRANT ZOALS EEN NIEUWSBERICHT, INTERVIEW EN COLUMN/HOROSCOOP/RIJBEWIJS WORDEN VEEL GELEZEN.
93. MIDDELEN OM SCHOON TE MAKEN ZOALS ZEEP, SCHUURMIDDEL EN BLEEK/VAATDOEK/PLINT RUIKEN MEESTAL LEKKER FRIS.
94. ZWEMTECHNIEKEN ZOALS BORSTCRAWL, SCHOOLSLAG EN VLINDERSLAG/DUIK/REGIO LEERT HIJ BIJ ZWEMLES.
95. ATTRACTIES OP DE KERMIS ZOALS DE DRAAIMOLEN, BOTSAUTO'S EN SCHIETTENT/SUIKERSPIN/KUS ZIJN MOOI VERSIERD.
96. DIEREN IN POOLGEBIEDEN ZOALS IJSBEREN, ZEEHONDEN EN PINGUÏNS/PLANKTON/CHIMPANSEES OVERLEVEN HET KOUDE KLIMAAT .

97. INSTRUMENTEN ZOALS TROMPET, KLARINET EN SAXOFOON/BARITON/KNOOP VEREISEN EEN GOEDE ADEMHALING.
98. FRISDRANKEN ZOALS COLA, SINAS EN CASSIS/RANJA/HEL WORDEN VEEL GEDRONKEN.
99. RAAMBEKLEDING ZOALS LUXAFLEX, GORDIJNEN EN LAMELLEN/HORREN/SCRIPTIES HOUDT LICHT TEGEN.
100. VERSCHILLENDE SOORTEN VLIEGTUIGEN ZOALS EEN SPORTVLIEGTUIG, HELIKOPTER EN STRAALJAGER/ ZEPPELIN/KNUFFEL GEBRUIKEN HET LUCHTRUIM.
101. ALCOHOLISCHE DRANKEN ZOALS BIER, WHISKY EN WIJN/MALT/PRUIM MOGEN HIER GENUTTIGD WORDEN.
102. VERSCHILLENDE DANSSTIJLEN ZOALS DE TANGO, WALS EN SALSA/CALYPSO/VORM KUN JE HIER LEREN.
103. FIETSEN ZOALS EEN RACEFIETS, OMAFIETS EN VOUWFIETS/GAZELLE/PROTEST GEBRUIKEN NEDERLANDERS VEEL.
104. WINTERKLEDING ZOALS DASSEN, MUTSEN EN HANDSCHOENEN/HEMDEN/ELASTIEK BESCHERMEN TEGEN DE KOU.
105. STERRENBEELDEN ZOALS STIER, TWEELING EN WEEGSCHAAL/DRAAK/KAM HANGEN AF VAN JE GEBOORTEDATUM.
106. APPARATEN IN DE KEUKEN ZOALS EEN KOELKAST, MAGNETRON EN OVEN/SPOELBAK/TAFEL HEBBEN STROOM NODIG.
107. TIJDSEENHEDEN ZOALS SECONDEN, MINUTEN EN UREN/NACHTEN/BLADZIJDEN GEVEN DE TIJDSDUUR AAN.
108. SPELLEN ZOALS KWARTET, DAMMEN EN GANZEBORD/TENNIS/BLIK SPELEN ZIJ GRAAG.
109. ZIJN ETUI MET ONDER ANDERE EEN PEN, POTLOOD EN GUM/KRIJT/SCHORT KAN HIJ NIET VINDEN.
110. WERKTUIGEN VOOR DE LANDBOUW ZOALS EEN PLOEG, TRACTOR EN HOOIWAGEN/KRUIWAGEN/PRIKBORD STAAN OP DE BOERDERIJ.
111. KATACHTIGEN ZOALS LEEUWEN, LUIPAARDEN EN PANTERS/POEZEN/KANGOEROES HEBBEN SCHERPE KLAUWEN.
112. TEXTIELMATERIALEN ZOALS ZIJDE, WOL EN LINNEN/GAAS/MAST WORDEN GEBRUIKT VOOR KOSTUUMS.
113. METALEN ZOALS IJZER, KOPER EN LOOD/KWIK/GRAS GELEIDEN WARMTE.
114. HEMELLICHAMEN ZOALS DE ZON, STERREN EN MAAN/RUIMTE/RIEM ZIJN NATUURLIJKE OBJECTEN.
115. VERVOERSMIDDELEN ZOALS AUTO'S, BUSSEN EN FIETSEN/STEPPEN/SCHOORSTENEN WORDEN VEEL GEBRUIKT.
116. MUNTEENHEDEN ZOALS DE EURO, POND EN DOLLAR/GULDEN/STRAAT KUNNEN PER LAND VERSCHILLEN.
117. KNAAGDIEREN ZOALS MUIZEN, HAMSTERS EN KONIJNEN/BEVERS/KANARIES LEVEN IN VERSCHILLENDE LEEFGEBIEDEN.
118. PLANTEN ZOALS EEN VAREN, FICUS EN KLIMOP/ZONNEBLOEM/GROND ZIJN VAAK GROEN.
119. CIRCUSARTIESTEN ZOALS EEN CLOWN, VUURSPUWER EN ACROBAAT/DANSERES/CONDUCTEUR REIZEN DE WERELD ROND.
120. TASSEN ZOALS EEN RUGTAS, SCHOUDERTAS EN HANDTAS/ZADELTAS/PET ZIJN VAAK VAN LEER.
121. ALLE SOORTEN FRUIT WAARONDER PEREN, BANANEN EN APPELS/OLIJVEN/BOERENKOOL BEVATTEN VITAMINEN.
122. STUDIES ZOALS RECHTEN, GENEESKUNDE EN WISKUNDE/HAVO/BETON HEBBEN EEN EIGEN VAKGEBIED.
123. ONZE ZINTUIGEN ZOALS GEHOOR, TAST EN ZICHT/NEUS/VUUR GEVEN ONS VOORTDUREND INFORMATIE.
124. DOOR VERSCHILLENDE MUZIEKSOORTEN ZOALS HOUSE, ROCK EN JAZZ/PIANO/MAT IS ER GENOEG KEUS.
125. SPORTEN ZOALS VOETBAL, HOCKEY EN BASKETBAL/SCHAKEN/ZAKDOEK WORDEN VEEL BEOEFEND.
126. ONS GEBIT MET ONDER ANDERE KIEZEN, SNIJTANDEN EN VOORTANDEN/GLAZUUR/LIJM MOETEN WE GOED POETSEN.
127. BLOEMEN ZOALS EEN LELIE, ROOS EN TULP/SERING/TERRAS RUIKEN VAAK LEKKER.
128. HONDENRASSEN ZOALS TECKELS, DALMATIËRS EN LABRADORS/PUPPY'S/VISSEN ZIJN ZEER GELIEFD.
129. GEDURENDE ELK DEEL VAN DE DAG ZOALS OCHTEND, MIDDAG EN AVOND/MINUUT/GRAF IS ER IEMAND AANWEZIG.
130. DELEN VAN EEN BESTEK ZOALS EEN MES, VORK EN LEPEL/GARDE/ZEBRAPAD VIND JE IN DE KEUKEN.
131. VORMEN ZOALS EEN DRIEHOEK, CIRKEL EN VIERKANT/HOEK/AFSCHEID WORDEN BIJ WISKUNDE GEBRUIKT.
132. DRANKEN VOOR BIJ HET ONTBIJT WAARONDER MELK, THEE EN KARNEMELK/APPELSAP/KARTON STAAN OP DIE TAFEL.
133. BROODBELEG ZOALS PINDAKAAS, CHOCOPASTA EN HAGELSLAG/PEPERKOEK/STRUIK WORDT VEEL VERKOCHT.
134. ADELLIJKE TITELS ZOALS BARON, GRAAF EN HERTOG/MASTER/RAAM STAAN HOOG AANGESCHREVEN.
135. VERSCHEIDENE PANNEN ZOALS EEN HAPJESPAN, WOK EN KOEKENPAN/FRITUURPAN/POLLEPEL KUNNEN TEGEN HITTE.
136. HET GENRE VAN EEN FILM ZOALS ACTIE, KOMEDIE EN HORROR/SPANNING/GEHEIM STAAT OP DE HOES.
137. DE GEREEDSCHAPSKIST MET DAARIN EEN SLEUTEL, TANG EN HAMER/ZAKLAMP/STROPDAS STAAT IN DE SCHUUR.
138. RANGEN IN HET LEGER ZOALS MAJOOR, KOLONEL EN SERGEANT/COMMANDO/JUF ZIJN ZEER BELANGRIJK.
139. HET SPEELGOED IN DIE DOOS WAARONDER AUTO'S, POPPEN EN BLOKKEN/BALLONNEN/WASKNIJPERS IS AL OUD.
140. HET GEREEDSCHAP VAN DE TIMMERMAN WAARONDER EEN HAMER, SPIJKERS EN ZAAG/LADDER/VIDEO LIGT OP DE GROND.
141. EDELSTENEN ZOALS SMARAGDEN, DIAMANTEN EN ROBIJNEN/ZILVER/THEEPOTTEN ZIJN ERG MOOI.

142. FAMILIELEDEN ZOALS EEN OOM, TANTE EN NEEF/STIEFVADER/INSTRUCTEUR KOMEN SOMS OP BEZOEK.
143. LEESMATERIAAL ZOALS BOEKEN, KRANTEN EN TIJDSCHRIFTEN/FOLDERS/FOSSIELEN VIND JE IN DE BIBLIOTHEEK.
144. IN EEN GEBOUW VOOR RELIGIEUZE DIENSTEN ZOALS EEN KERK, TEMPEL EN MOSKEE/KAPEL/SPORTHAL HEERST VAAK RUST.
145. EEN MISDAAD ZOALS EEN VERKRACHTING, OVERVAL EN MOORD/ZELFMOORD/APPLAUS MOET GESTRAFT WORDEN.
146. DELEN VAN EEN GEBOUW ZOALS DE RAMEN, DEUREN EN MUREN/TAPIJTEN/MOTOREN DIENEN STEVIG TE ZIJN.
147. IN BEROEPEN ZOALS DOKTER, LERAAR EN ADVOCAAT/ATLEET/MENS IS HIJ NIET GEÏNTERESSEERD.
148. AMERIKAANSE STATEN ZOALS TEXAS, CALIFORNIË EN FLORIDA/MEXICO/KASSA KUNNEN DEELS ONAFHANKELIJK OPEREREN.
149. HAARKLEUREN ZOALS BLOND, BRUIN EN ZWART/PAARS/KWAST WORDEN BEPAALD DOOR PIGMENTEN.
150. COMPUTER APPARATUUR ZOALS EEN MUIS, TOETSENBORD EN BEELDSCHERM/KABEL/PAPIER IS HIER TE KOOP.
151. DINGEN OM MEE TE SCHRIJVEN ZOALS EEN STIFT, POTLOOD EN PEN/VEER/BEZEMSTEEL LIGGEN IN DE LA.
152. VOORWERPEN OM UIT TE DRINKEN ZOALS EEN BEKER, GLAS EN MOK/KOM/SERVET STAAN IN HET KASTJE.
153. HET CONTACT PER BRIEF, MAIL EN TELEFOON/MORSE/WATERTANK VERLOOPT MEESTAL SOEPEL.
154. DIE ADRESGEGEVENS WAARONDER ZIJN POSTCODE, STRAAT EN PLAATS/WIJK/BUREAUSTOEL ZIJN NIET TE ACHTERHALEN.
155. KANTOORARTIKELEN ZOALS PAPERCLIPS, PLAKBAND EN NIETJES/LAPTOPS/WORTELS WORDEN VAAK GROOT INGEKOCHT.
156. ZIJN VISUITRUSTING BESTAANDE UIT ONDER ANDERE EEN NET, DOBBER EN HENGEL/SLOEP/WOLK IS NET NIEUW.
157. MAKE-UP PRODUCTEN ZOALS OOGSCHADUW, LIPPENSTIFT EN MASCARA/SCHMINK/HOUT ZIJN VAAK ERG DUUR.
158. OP DE MARKT STAAN VERKOPERS VAN VIS, BLOEMEN EN KLEDING/STOFZUIGERS/SNEEUW OM GELD TE VERDIENEN.
159. ONDERDELEN VAN EEN FIETS ZOALS EEN STUUR, ZADEL EN WIEL/MAND/HEK KUNNEN KAPOT GAAN.
160. PRIJZEN ZOALS BEKERS, LINTJES EN MEDAILLES/BONNEN/STOKKEN ZIJN VOOR DE WINNAARS.
161. VOOR FEESTDAGEN ZOALS PASEN, KERSTMIS EN PINKSTEREN/CARNAVAL/PENSEEL KRIJGT MEN VRIJ.
162. EEN BOOM BESTAANDE UIT EEN STAM, TAKKEN EN BLADEREN/BLOESEM/SLEUTELS KAN HEEL OUD WORDEN.

References

Arzouan, Y., Goldstein, A., & Faust, M. (2007). Brainwaves are stethoscopes: ERP correlates of novel metaphor comprehension. *Brain Research, 1160*, 69-81.

Baayen, R. H., Piepenbrock, R., & Gulikers, L. (1995). *The CELEX lexical database [CD-ROM]*. Philadelphia: University of Pennsylvania, Linguistic Data Consortium.

Badre, D., & Wagner, A. D. (2004). Selection, integration, and conflict monitoring: Assessing the nature and generality of prefrontal cognitive control mechanisms. *Neuron, 41*(3), 473-487.

Badre, D., & Wagner, A. D. (2007). Left ventrolateral prefrontal cortex and the cognitive control of memory. *Neuropsychologia, 45*(13), 2883-2901.

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

Bookheimer, S. (2002). Functional MRI of language: New approaches to understanding the cortical organization of semantic processing. *Annual Review of Neuroscience, 25*(1), 151-188.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108*(3), 624-652.

Botvinick, M. M., Cohen, J. D., & Carter, C. S. (2004). Conflict monitoring and anterior cingulate cortex: An update. *Trends in Cognitive Sciences, 8*(12), 539-546.

Brett, M., Anton, J.-L., Valabregue, R., & Poline, J.-B. (2002). *Region of interest analysis using an SPM toolbox.* Paper presented at the 8th International Conference on Functional Mapping of the Human Brain, Sendai, Japan.

Chwilla, D. J., & Brunia, C. H. M. (1991). Event-related potential correlates of non-motor anticipation. *Biological Psychology, 32*(2-3), 125-141.

Chwilla, D. J., Hagoort, P., & Brown, C. M. (1998). The Mechanism Underlying Backward Priming in a Lexical Decision Task: Spreading Activation versus Semantic Matching. *The Quarterly Journal of Experimental Psychology Section A, 51*(3), 531-560.

Chwilla, D. J., & Kolk, H. H. J. (2002). Three-step priming in lexical decision. *Memory & Cognition, 30*(2), 217-225.

Chwilla, D. J., & Kolk, H. H. J. (2005). Accessing world knowledge: Evidence from N400 and reaction time priming. *Cognitive Brain Research, 25*(3), 589-606.

Chwilla, D. J., Kolk, H. H. J., & Mulder, G. (2000). Mediated priming in the lexical decision task: Evidence from event-related potentials and reaction time. *Journal of Memory and Language, 42*(3), 314-341.

Chwilla, D. J., Virgillito, D., & Vissers, C. T. W. M. (2010). The Relationship of Language and Emotion: N400 Support for an Embodied View of Language Comprehension. *Journal of Cognitive Neuroscience, 23*(9), 2400-2414.

Coenen, A. M. L. (1995). Neuronal activities underlying the electroencephalogram and evoked potentials of sleeping and waking: Implications for information processing. *Neuroscience & Biobehavioral Reviews, 19*(3), 447-463.

Cohen, J. D., Botvinick, M., & Carter, C. S. (2000). Anterior cingulate and prefrontal cortex: Who's in control? *Nature Neuroscience, 3*(5), 421-423.

Coles, M. G. H., Scheffers, M. K., & Holroyd, C. B. (2001). Why is there an ERN/Ne on correct trials? Response representations, stimulus-related components, and the theory of error-processing. *Biological Psychology, 56*(3), 173-189.

Cooke, A., Grossman, M., DeVita, C., Gonzalez-Atavales, J., Moore, P., Chen, W., et al. (2006). Large-scale neural network for sentence processing. *Brain and Language, 96*(1), 14-36.

Coulson, S., King, J. W., & Kutas, M. (1998). Expect the unexpected: Event-related brain response to morphosyntactic violations. *Language and Cognitive Processes, 13*(1), 21-58.

Coulson, S., & Van Petten, C. (2002). Conceptual integration and metaphor: An event-related potential study. *Memory & Cognition, 30*(6), 958-968.

Cutler, A., & Butterfield, S. (1992). Rhythmic cues to speech segmentation: Evidence from juncture misperception. *Journal of Memory and Language, 31*(2), 218-236.

Dehaene, S., Le Clec'H, G., Poline, J.-B., Le Bihan, D., & Cohen, L. (2002). The visual word form area: A prelexical representation of visual words in the fusiform gyrus. *NeuroReport, 13*(3), 321-325.

Derrfuss, J., Brass, M., & Yves von Cramon, D. (2004). Cognitive control in the posterior frontolateral cortex: evidence from common activations in task coordination, interference control, and working memory. *NeuroImage, 23*(2), 604-612.

Donchin, E. (1981). Surprise!… Surprise? *Psychophysiology, 18*(5), 493-513.

Donchin, E., & Coles, M. G. H. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences, 11*(3), 357-374.

Dronkers, N. F., Wilkins, D. P., Van Valin Jr, R. D., Redfern, B. B., & Jaeger, J. J. (2004). Lesion analysis of the brain areas involved in language comprehension. *Cognition, 92*(1-2), 145-177.

Duncan, J., & Owen, A. M. (2000). Common regions of the human frontal lobe recruited by diverse cognitive demands. *Trends in Neurosciences, 23*(10), 475-483.

Embick, D., Marantz, A., Miyashita, Y., O'Neil, W., & Sakai, K. L. (2000). A syntactic specialization for Broca's area. *Proceedings of the National Academy of Sciences of the United States of America, 97*(11), 6150-6154.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*(1), 143-149.

Federmeier, K. D., & Kutas, M. (1999). A rose by any other name: Long-term memory structure and sentence processing. *Journal of Memory and Language, 41*(4), 469-495.

Federmeier, K. D., Wlotko, E. W., De Ochoa-Dewald, E., & Kutas, M. (2007). Multiple effects of sentential constraint on word processing. *Brain Research, 1146*, 75-84.

Fiebach, C. J., Schlesewsky, M., Lohmann, G., Von Cramon, D. Y., & Friederici, A. D. (2005). Revisiting the role of Broca's area in sentence processing: Syntactic integration versus syntactic working memory. *Human Brain Mapping, 24*(2), 79-91.

Fodor, J. A. (1983). *The modularity of mind: An essay on faculty psychology*. Cambridge, MA: MIT Press.

Ford, J. M., Woodward, S. H., Sullivan, E. V., Isaacks, B. G., Tinklenberg, J. R., Yesavage, J. A., et al. (1996). N400 evidence of abnormal responses to speech in Alzheimer's disease. *Electroencephalography and Clinical Neurophysiology, 99*(3), 235-246.

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

Friederici, A. D., Makuuchi, M., & Bahlmann, J. (2009). The role of the posterior superior temporal cortex in sentence comprehension. *NeuroReport, 20*(6), 563-568.

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*(3), 183-192.

Friederici, A. D., Ruschemeyer, S.-A., Hahne, A., & Fiebach, C. J. (2003). The role of left inferior frontal and superior temporal cortex in sentence comprehension: Localizing syntactic and semantic processes. *Cereb Cortex, 13*(2), 170-177.

Ganushchak, L. Y., & Schiller, N. O. (2010). Detection of speech errors in the speech of others: An erp study. *NeuroImage, 49*, 3331-3337.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2002). *Cognitive Neuroscience: The biology of the mind* (2nd ed.). New York: W.W. Norton & Company.

Goodglass, H., & Berko, J. (1960). Agrammatism and inflectional morphology in English. *Journal of Speech and Hearing Research, 3*(3), 257-267.

Grodzinsky, Y. (2000). The neurology of syntax: Language use without Broca's area. *Behavioral and Brain Sciences, 23*, 1-71.

Grodzinsky, Y., & Friederici, A. D. (2006). Neuroimaging of syntax and syntactic processing. *Current Opinion in Neurobiology, 16*(2), 240-246.

Grodzinsky, Y., & Santi, A. (2008). The battle for Broca's region. *Trends in Cognitive Sciences, 12*(12), 474-480.

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), 556-568.

Gunter, T. C., Jackson, J. L., & Mulder, G. (1992). An Electrophysiological Study of Semantic Processing in Young and Middle-Aged Academics. *Psychophysiology, 29*(1), 38-54.

Gunter, T. C., Stowe, L. A., & Mulder, G. (1997). When syntax meets semantics. *Psychophysiology, 34*(6), 660-676.

Hagoort, P. (2003). How the brain solves the binding problem for language: a neurocomputational model of syntactic processing. *Neuroimage, 20*, S18-S29.

Hagoort, P. (2005). On Broca, brain, and binding: a new framework. *Trends in Cognitive Sciences, 9*(9), 416-423.

Hagoort, P. (2009). Reflections on the neurobiology of syntax. In D. Bickerton & E. Szathmáry (Eds.), *Biological foundations and origin of syntax* (pp. 279-296). Cambridge, MA: The MIT Press.

Hagoort, P., Baggio, G., & Willems, R. M. (2009). Semantic unification. In M. S. Gazzaniga (Ed.), *The New Cognitive Neurosciences* (4th ed., pp. 819-836). Cambridge, MA: MIT Press.

Hagoort, P., Brown, C., & Groothusen, J. (1993). The Syntactic Positive Shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes, 8*(4), 439-483.

Hagoort, P., & Brown, C. M. (2000). ERP effects of listening to speech compared to reading: The P600/SPS to syntactic violations in spoken sentences and rapid serial visual presentation. *Neuropsychologia, 38*(11), 1531-1549.

Hagoort, P., Brown, C. M., & Osterhout, L. (1999). The neurocognition of syntactic processing. In C. M. Brown & P. Hagoort (Eds.), *The neurocognition of language* (pp. 273 - 317). Oxford: Oxford University Press.

Hanulíková, A., van Alphen, P. M., van Goch, M. M., & Weber, A. (in press). When One Person's Mistake Is Another's Standard Usage: The Effect of Foreign Accent on Syntactic Processing. *Journal of Cognitive Neuroscience*.

Heinze, H.-J., Muente, T.-F., & Kutas, M. (1998). Context effects in a category verification task as assessed by event-related brain potential (ERP) measures. *Biological Psychology, 47*(2), 121-135.

Hoeks, J. C. J., Stowe, L. A., & Doedens, G. (2004). Seeing words in context: the interaction of lexical and sentence level information during reading. *Cognitive Brain Research, 19*(1), 59-73.

Holcomb, P. J. (1993). Semantic priming and stimulus degradation: Implications for the role of the N400 in language processing. *Psychophysiology, 30*(1), 47-61.

Holcomb, P. J., & Neville, H. J. (1990). Auditory and Visual Semantic Priming in Lexical Decision: A Comparison Using Event-related Brain Potentials. *Language and Cognitive Processes, 5*(4), 281-312.

Holroyd, C. B., & Coles, M. G. H. (2002). The neural basis of human error processing: Reinforcement learning, dopamine, and the Error-Related Negativity. *Psychological Review, 109*(4), 679-709.

Indefrey, P., Hagoort, P., Herzog, H., Seitz, R. J., & Brown, C. M. (2001). Syntactic processing in left prefrontal cortex is independent of lexical meaning. *NeuroImage, 14*(3), 546-555.

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. *Journal of Cognitive Neuroscience, 21*(12), 2434-2444.

Jonides, J., Smith, E. E., Marshuetz, C., Koeppe, R. A., & Reuter-Lorenz, P. A. (1998). Inhibition in verbal working memory revealed by brain activation. *Proceedings of the National Academy of Sciences, 95*(14), 8410-8413.

Kaan, E., Harris, A., Gibson, E., & Holcomb, P. (2000). The P600 as an index of syntactic integration difficulty. *Language and Cognitive Processes, 15*(2), 159 - 201.

Kaan, E., & Swaab, T. Y. (2003). Repair, revision, and complexity in syntactic analysis: An electrophysiological differentiation. *Journal of Cognitive Neuroscience, 15*(1), 98-110.

Kahneman, D. (1973). *Attention and effort.* Englewood Cliffs: Prentice-Hall.

Kang, A. M., Constable, R. T., Gore, J. C., & Avrutin, S. (1999). An event-related fMRI study of implicit phrase-level syntactic and semantic processing. *NeuroImage, 10*(5), 555-561.

Kaufman, R. C., & Obler, L. K. (1995). Classification of normal reading error types. In C. K. Leong & R. M. Joshi (Eds.), *Developmental and acquired dyslexia: Neuropsychological and neurolinguistic perspectives* (pp. 149-157). Dordrecht: Kluwer Academic Publishers.

Kim, A., & Osterhout, L. (2005). The independence of combinatory semantic processing: Evidence from event-related potentials. *Journal of Memory and Language, 52*(2), 205-225.

Kok, A., & Looren de Jong, H. (1980). Components of the event-related potential following degraded and undegraded visual stimuli. *Biological Psychology, 11*(2), 117-133.

Kolk, H. H. J., & Chwilla, D. J. (2007). Late positivities in unusual situations. *Brain and Language, 100*(3), 257-261.

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.

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

Kuperberg, G. R. (2009). Understanding events: Streams of language processing in the brain. Talk given at the Donders Institute for Brain, Cognition and Behaviour. Nijmegen, The Netherlands.

Kuperberg, G. R., Caplan, D., Sitnikova, T., Eddy, M., & Holcomb, P. (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), 272-293.

Kuperberg, G. R., Kreher, D. A., Sitnikova, T., Caplan, D. N., & Holcomb, P. J. (2007). The role of animacy and thematic relationships in processing active English sentences: Evidence from event-related potentials. *Brain and Language, 100*(3), 223-237.

Kuperberg, G. R., McGuire, P. K., Bullmore, E. T., Brammer, M. J., Rabe-Hesketh, S., Wright, I. C., et al. (2000). Common and distinct neural substrates for pragmatic, semantic, and syntactic processing of spoken sentences: An fMRI study. *Journal of Cognitive Neuroscience, 12*(2), 321-341.

Kuperberg, G. R., Sitnikova, T., Caplan, D., & Holcomb, P. J. (2003). Electrophysiological distinctions in processing conceptual relationships within simple sentences. *Cognitive Brain Research, 17*(1), 117-129.

Kuperberg, G. R., Sitnikova, T., & Lakshmanan, B. M. (2008). Neuroanatomical distinctions within the semantic system during sentence comprehension: Evidence from functional magnetic resonance imaging. *NeuroImage, 40*(1), 367-388.

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences, 4*(12), 463-470.

Kutas, M., & Hillyard, S. A. (1980a). Event-related brain potentials to semantically inappropriate and surprisingly large words. *Biological Psychology, 11*(2), 99-116.

Kutas, M., & Hillyard, S. A. (1980b). Reading between the lines: Event-related brain potentials during natural sentence processing. *Brain and Language, 11*(2), 354-373.

Kutas, M., & Hillyard, S. A. (1980c). Reading senseless sentences: brain potentials reflect semantic incongruity. *Science, 207*, 203-205.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature, 307*(5947), 161-163.

Kutas, M., Van Petten, C., & Kluender, R. (2006). Psycholinguistics electrified II: 1994-2005. In M. Traxler & M. A. Gernsbacher (Eds.), *Handbook of psycholinguistics, 2nd edition* (pp. 659-724). New York: Elsevier.

Kutas, M., & Van Petten, C. K. (1994). Psycholinguistics electrified: Event-related brain potential investigations. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 83-143). San Diego, CA: Academic Press.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). An introduction to latent semantic analysis. *Discourse Processes, 25*(2-3), 259-284.

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics: (de)constructing the N400. *Nature Reviews Neuroscience, 9*(12), 920-933.

Lelekov-Boissard, T., & Dominey, P. F. (2002). Human brain potentials reveal similar processing of non-linguistic abstract structure and linguistic syntactic structure. *Clinical Neurophysiology, 32*, 72-84.

Levelt, W. J. M. (1983). Monitoring and self-repair in speech. *Cognition, 14*(1), 41-104.

Levelt, W. J. M. (1989). *Speaking : from intention to articulation*. Cambridge, MA: The MIT Press.

Luck, S. J., & Hillyard, S. A. (1994). Electrophysiological correlates of feature analysis during visual search. *Psychophysiology, 31*(3), 291-308.

Mackay, D. G. (1987). *The organization of perception and action : a theory for language and other cognitive skills* New York: Springer.

MacKay, D. G. (1990). Perception, action, and awareness: A three-body problem. In O. Neumann & W. Prinz (Eds.), *Relationships between perception and action: Current approaches* (pp. 269-303). Berlin: Springer-Verlag.

MacKay, D. G. (1992). Awareness and error detection: New theories and research paradigms. *Consciousness and Cognition, 1*(3), 199-225.

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, & Cognition, 29*(6), 1319-1338.

McCarthy, G., & Wood, C. C. (1985). Scalp distributions of event-related potentials: An ambiguity associated with analysis of variance models. *Electroencephalography and Clinical Neurophysiology, 62*, 203-208.

McGuire, P. K., Silbersweig, D. A., & Frith, C. D. (1996). Functional neuroanatomy of verbal self-monitoring. *Brain, 119*(3), 907-917.

Mechelli, A., Gorno-Tempini, M. L., & Price, C. J. (2003). Neuroimaging studies of word and pseudoword reading: Consistencies, inconsistencies, and limitations. *Journal of Cognitive Neuroscience, 15*(2), 260-271.

Mecklinger, A., Schriefers, H., Steinhauer, K., & Friederici, A. (1995). Processing relative clauses varying on syntactic and semantic dimensions: An analysis with event-related potentials. *Memory & Cognition, 23*(4), 477-494.

Meyer, M., Friederici, A. D., & von Cramon, D. Y. (2000). Neurocognition of auditory sentence comprehension: event related fMRI reveals sensitivity to syntactic violations and task demands. *Cognitive Brain Research, 9*(1), 19-33.

Milham, M. P., Banich, M. T., & Barad, V. (2003). Competition for priority in processing increases prefrontal cortex's involvement in top-down control: an event-related fMRI study of the stroop task. *Cognitive Brain Research, 17*(2), 212-222.

Milham, M. P., Banich, M. T., Webb, A., Barad, V., Cohen, N. J., Wszalek, T., et al. (2001). The relative involvement of anterior cingulate and prefrontal cortex in attentional control depends on nature of conflict. *Cognitive Brain Research, 12*(3), 467-473.

Miller, E. K. (2000). The prefontral cortex and cognitive control. *Nature Reviews Neuroscience, 1*(1), 59-65.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24*(1), 167-202.

Moro, A., Tettamanti, M., Perani, D., Donati, C., Cappa, S. F., & Fazio, F. (2001). Syntax and the brain: Disentangling grammar by selective anomalies. *NeuroImage, 13*(1), 110-118.

Münte, T. F., Heinze, H.-J., Matzke, M., Wieringa, B. M., & Johannes, S. (1998). Brain potentials and syntactic violations revisited: no evidence for specificity of the syntactic positive shift. *Neuropsychologia, 36*(3), 217-226.

Nakano, H., Saron, C., & Swaab, T. Y. (2009). Speech and span: Working memory capacity impacts the use of animacy but not of world knowledge during spoken sentence comprehension. *Journal of Cognitive Neuroscience, 22*(12), 2886-2898.

Nee, D. E., Wager, T. D., & Jonides, J. (2007). Interference resolution: Insights from a meta-analysis of neuroimaging tasks. *Cognitive, Affective, & Behavioral Neuroscience, 7*(1), 1-17.

Nelson, J. K., Reuter-Lorenz, P. A., Sylvester, C.-Y. C., Jonides, J., & Smith, E. E. (2003). Dissociable neural mechanisms underlying response-based and familiarity-based conflict in working memory. *Proceedings of the National Academy of Sciences, 100*(19), 11171-11175.

Newman, R. L., & Connolly, J. F. (2004). Determining the role of phonology in silent reading using event-related brain potentials. *Cognitive Brain Research, 21*(1), 94-105.

Nichelli, P., Grafman, J., Pietrini, P., Clark, K., Lee, K. Y., & Miletich, R. (1995). Where the brain appreciates the moral of a story. *NeuroReport, 6*, 2309-2313.

Nieuwland, M. S., & Van Berkum, J. J. A. (2005). Testing the limits of the semantic illusion phenomenon: ERPs reveal temporary semantic change deafness in discourse comprehension. *Cognitive Brain Research, 24*(3), 691-701.

Novick, J. M., Kan, I. P., Trueswell, J. C., & Thompson-Schill, S. L. (2009). A case for conflict across multiple domains: Memory and language impairments following damage to ventrolateral prefrontal cortex. *Cognitive Neuropsychology, 26*(6), 527 - 567.

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.

Núñez-Peña, M. I., & Honrubia-Serrano, M. L. (2004). P600 related to rule violation in an arithmetic task. *Cognitive Brain Research, 18*(2), 130-141.

Núñez-Peña, M. I., & Honrubia-Serrano, M. L. (2005). N400 and category exemplar associative strength. *International Journal of Psychophysiology, 56*(1), 45-54.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*(1), 97-113.

Osterhout, L. (1997). On the Brain Response to Syntactic Anomalies: Manipulations of Word Position and Word Class Reveal Individual Differences. *Brain and Language, 59*(3), 494-522.

Osterhout, L., & 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 and Cognitive Processes, 14*(1), 1-14.

Osterhout, L., & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language, 31*(6), 785-806.

Osterhout, L., & Holcomb, P. J. (1993). Event-related potentials and syntactic anomaly: Evidence of anomaly detection during the perception of continuous speech. *Language and Cognitive Processes, 8*(4), 413-437.

Osterhout, L., McKinnon, R., Bersick, M., & Corey, V. (1996). On the language specificity of the brain response to syntactic anomalies: Is the syntactic positive shift a member of the p300 family? *J. Cognitive Neuroscience, 8*(6), 507-526.

Osterhout, L., & Mobley, L. A. (1995). Event-Related Brain Potentials Elicited by Failure to Agree. *Journal of Memory and Language, 34*(6), 739-773.

Patel, A. D., Gibson, E., Ratner, J., Besson, M., & Holcomb, P. J. (1998). Processing syntactic relations in language and music: An event-related potential study. *Journal of Cognitive Neuroscience, 10*(6), 717-733.

Poser, B. A., & Norris, D. G. (2009). Investigating the benefits of multi-echo EPI for fMRI at 7 T. *NeuroImage, 45*(4), 1162-1172.

Poser, B. A., Versluis, M. J., Hoogduin, J. M., & Norris, D. G. (2006). BOLD contrast sensitivity enhancement and artifact reduction with multiecho EPI: Parallel-acquired inhomogeneity-desensitized fMRI. *Magnetic Resonance in Medicine, 55*(6), 1227-1235.

Postma, A. (2000). Detection of errors during speech production: a review of speech monitoring models. *Cognition, 77*(2), 97-132.

Pynte, J., Besson, M., Robichon, F.-H., & Poli, J. (1996). The Time-Course of Metaphor Comprehension: An Event-Related Potential Study. *Brain and Language, 55*(3), 293-316.

Ridderinkhof, K. R., Ullsperger, M., Crone, E. A., & Nieuwenhuis, S. (2004). The Role of the Medial Frontal Cortex in Cognitive Control. *Science, 306*(5695), 443-447.

Ridderinkhof, K. R., van den Wildenberg, W. P. M., Segalowitz, S. J., & Carter, C. S. (2004). Neurocognitive mechanisms of cognitive control: The role of prefrontal cortex in action selection, response inhibition, performance monitoring, and reward-based learning. *Brain and Cognition, 56*(2), 129-140.

Robinson, G., Blair, J., & Cipolotti, L. (1998). Dynamic aphasia: An inability to select between competing verbal responses? *Brain, 121*, 77-89.

Rockstroh, B., Müller, M., Cohen, R., & Elbet, T. (1992). Probing the functional brain state during P300-evocation. 1992. *Journal of Psychophysiology, 6*, 175-184.

Rockstroh, B., Muller, M., Heinz, A., Wagner, M., Berg, P., & Elbert, T. (1996). Modulation of auditory responses during oddball tasks. *Biological Psychology, 43*, 41-55.

Roehm, D., Bornkessel-Schlesewsky, I., Rösler, F., & Schlesewsky, M. (2007). To Predict or Not to Predict: Influences of Task and Strategy on the Processing of Semantic Relations. *Journal of Cognitive Neuroscience, 19*(8), 1259-1274.

Ruchkin, D. S., Johnson, R., Mahaffey, D., & Sutton, S. (1988). Toward a Functional Categorization of Slow Waves. *Psychophysiology, 25*(3), 339-353.

Schwartz, T. J., Kutas, M., Butters, N., Paulsen, J. S., & Salmon, D. P. (1996). Electrophysiological insights into the nature of the semantic deficit in Alzheimer's disease. *Neuropsychologia, 34*(8), 827-841.

Sitnikova, T., Holcomb, P. J., Kiyonaga, K. A., & Kuperberg, G. R. (2008). Two neurocognitive mechanisms of semantic integration during the comprehension of visual real-world events. *Journal of Cognitive Neuroscience, 20*(11), 2037-2057.

Stroop, J. R. (1935). Studies on interference in serial verbal reactions. *Journal of Experimental Psychology, 18*(6), 643-662.

Stuss, D. T., & Benson, D. F. (1986). *The frontal lobes*. New York: Raven Press.

Swick, D., Kutas, M., & Knight, R. T. (1998). Prefrontal lesions eliminate the LPC but do not affect the N400 during sentence reading. *Journal of Cognitive Neuroscience Supplement, 5.29*.

Thompson-Schill, S. L., Bedny, M., & Goldberg, R. F. (2005). The frontal lobes and the regulation of mental activity. *Current Opinion in Neurobiology, 15*(2), 219-224.

Thompson-Schill, S. L., D'Esposito, M., Aguirre, G. K., & Farah, M. J. (1997). Role of left inferior prefrontal cortex in retrieval of semantic knowledge: A reevaluation. *Proceedings of the National Academy of Sciences of the United States of America, 94*(26), 14792-14797.

Thompson-Schill, S. L., Jonides, J., Marshuetz, C., Smith, E., D'Esposito, M., Kan, I., et al. (2002). Effects of frontal lobe damage on interference effects in working memory. *Cognitive, Affective, & Behavioral Neuroscience, 2*(2), 109-120.

Tzourio-Mazoyer, N., Landeau, B., Papathanassiou, D., Crivello, F., Etard, O., Delcroix, N., et al. (2002). Automated anatomical labelling of activations in spm using a macroscopic anatomical parcellation of the MNI MRI single subject brain. *Neuroimage, 15*, 273-289.

Urbach, T. P., & Kutas, M. (2002). The intractability of scaling scalp distributions to infer neuroelectric sources. *Psychophysiology, 39*(6), 791-808.

Urbach, T. P., & Kutas, M. (2006). Interpreting event-related brain potential (ERP) distributions: Implications of baseline potentials and variability with application to amplitude normalization by vector scaling. *Biological Psychology, 72*(3), 333-343.

Van Berkum, J. J. A., Hagoort, P., & Brown, C. M. (1999). Semantic Integration in Sentences and Discourse: Evidence from the N400. *Journal of Cognitive Neuroscience, 11*(6), 657-671.

Van de Meerendonk, N., Chwilla, D. J., & Kolk, H. H. J. (submitted). States of indecision in the brain: ERP reflections of representational conflicts and word degradation.

Van de Meerendonk, N., Indefrey, P., Chwilla, D. J., & Kolk, H. H. J. (2011). Monitoring in language perception: Electrophysiological and hemodynamic responses to spelling violations. *NeuroImage, 54*(3), 2350-2363.

Van de Meerendonk, N., Kolk, H. H. J., Chwilla, D. J., & Vissers, C. T. W. M. (2009). Monitoring in language perception. *Language and Linguistics Compass, 3*(5), 1211-1224.

Van de Meerendonk, N., Kolk, H. H. J., Vissers, C. T. W. M., & Chwilla, D. J. (2010). Monitoring in language perception: Mild and strong conflicts elicit different ERP patterns. *Journal of Cognitive Neuroscience, 22*(1), 67-82.

Van de Meerendonk, N., Rueschemeyer, S.-A., & Kolk, H. H. J. (submitted). Not only syntactic and semantic anomalies but also word degradation colocalize with the Stroop task in Broca's area.

Van Herten, M., Chwilla, D. J., & Kolk, H. H. J. (2006). When heuristics clash with parsing routines: ERP evidence for conflict monitoring in sentence perception. *Journal of Cognitive Neuroscience, 18*(7), 1181-1197.

Van Herten, M., Kolk, H. H. J., & Chwilla, D. J. (2005). An ERP study of P600 effects elicited by semantic anomalies. *Cognitive Brain Research, 22*(2), 241-255.

Van Petten, C., & Luka, B. J. (2006). Neural localization of semantic context effects in electromagnetic and hemodynamic studies. *Brain and Language, 97*(3), 279-293.

Vasey, M. W., & Thayer, J. F. (1987). The continuing problem of false positives in repeated measures ANOVA in psychophysiology: A multivariate solution. *Psychophysiology, 24*(4), 479-486.

Vissers, C. T. W. M. (2008). *Monitoring in language perception: An electrophysiological investigation*. Doctoral dissertation, Radboud University Nijmegen.

Vissers, C. T. W. M., Chwilla, D. J., & Kolk, H. H. J. (2006). Monitoring in language perception: The effect of misspellings of words in highly constrained sentences. *Brain Research, 1106*(1), 150-163.

Vissers, C. T. W. M., Chwilla, D. J., & Kolk, H. H. J. (2007). The interplay of heuristics and parsing routines in sentence comprehension: Evidence from ERPs and reaction times. *Biological Psychology, 75*(1), 8-18.

Vissers, C. T. W. M., Kolk, H. H. J., Van de Meerendonk, N., & Chwilla, D. J. (2008). Monitoring in language perception: Evidence from ERPs in a picture-sentence matching task. *Neuropsychologia, 46*(4), 967-982.

Vos, S. H., Gunter, T. C., Kolk, H. H. J., & Mulder, G. (2001). Working memory constraints on syntactic processing: An electrophysiological investigation. *Psychophysiology, 38*(01), 41-63.

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), 105-143.

Wartenburger, I., Heekeren, H. R., Burchert, F., Heinemann, S., De Bleser, R., & Villringer, A. (2004). Neural correlates of syntactic transformations. *Human Brain Mapping, 22*(1), 72-81.

Wilding, E. L. (2006). The practice of rescaling scalp-recorded event-related potentials. *Biological Psychology, 72*(3), 325-332.

Woodward, S. H., Ford, J. M., & Hammett, S. C. (1993). N4 to spoken sentences in young and older subjects. *Electroencephalography and Clinical Neurophysiology, 87*(5), 306-320.

Ye, Z., & Zhou, X. (2008). Involvement of cognitive control in sentence comprehension: Evidence from ERPs. *Brain Research, 1203*, 103-115.

Ye, Z., & Zhou, X. (2009a). Conflict control during sentence comprehension: fMRI evidence. *NeuroImage, 48*(1), 280-290.

Ye, Z., & Zhou, X. (2009b). Executive control in language processing. *Neuroscience & Biobehavioral Reviews, 33*(8), 1168-1177.

Yeung, N., Botvinick, M. M., & Cohen, J. D. (2004). The neural basis of error detection: Conflict monitoring and the error-related negativity. *Psychological Review, 111*(4), 931-959.

Samenvatting

We beschouwen taal over het algemeen als iets vanzelfsprekends. Zo gebruiken we taal om onszelf te kunnen uiten en om anderen te begrijpen. Elke dag produceren we en zien of horen we honderden woorden, die we met elkaar combineren tot betekenisvolle zinnen. Normaalgesproken begrijpen we moeiteloos wat een ander zegt of schrijft, maar soms ontstaat er twijfel en vragen we ons af: 'Heb ik dat wel goed gehoord/gelezen?'. In dit proefschrift onderzoek ik juist deze situaties waarin het taalbegrip tijdelijk verstoord is. Ik veronderstel dat een cognitief controleproces, genaamd 'monitoren', een belangrijke rol speelt bij het voorkomen van daadwerkelijke misverstanden.

Monitoren

Monitoren is een proces dat de kwaliteit van ons gedrag bewaakt. Het is een proces dat beoordeelt hoeveel controle er nodig is en aanpassingen in controle in gang kan zetten. Een vraag is echter hoe het systeem weet dat er aanpassingen in de controle nodig zijn. Uit bevindingen in het actiedomein, waarbij veel onderzoek is gedaan naar het monitoren voor fouten, komt naar voren dat de aanwezigheid van een conflict in de informatieverwerking een belangrijk signaal voor onze hersenen is dat er aanpassingen in de controle nodig zijn. Er is sprake van een conflict wanneer onze intenties of verwachtingen niet overeenkomen met wat we daadwerkelijk doen of waarnemen. Wanneer een conflict gedetecteerd wordt, leidt dit tot aanpassingen om het probleem op te lossen (e.g., Botvinick e.a., 2001).

Ook in het domein van de taalproductie wordt aangenomen dat een proces van monitoren ervoor waakt dat we fouten in onze spraak ontdekken en deze corrigeren. In taalproductie leidt dit vaak tot hoorbare zelf-reparaties. Een zelf-reparatie doet zich bijvoorbeeld voor wanneer we iemand de weg wijzen en zeggen: "Op de rotonde neemt u de eerste, eh… de tweede afslag". Dit voorbeeld laat zien dat we in staat zijn om te ontdekken wanneer onze uitingen niet overeenkomen met onze intenties. Tevens laat het zien dat, naast het ontdekken van een dergelijk conflict, we in staat zijn om de fout te corrigeren.

Behalve fouten in de taalproductie kunnen ook bij het waarnemen van taal fouten worden gemaakt. Soms maken we bijvoorbeeld een fout bij het lezen van een woord, of we verstaan iemand verkeerd. Deze fouten in de taalwaarneming kunnen we niet direct observeren, omdat ze niet leiden tot waarneembaar gedrag zoals zelf-reparaties in spraak, en omdat we niet weten wat de bedoelingen zijn van de spreker of schrijver. Hoe worden deze fouten in de taalwaarneming dan toch opgemerkt? Volgens de monitoringtheorie van de taalwaarneming, die is voorgesteld door Kolk e.a. (2003), zorgt een conflict tussen een verwacht en een geobserveerd linguïstisch element – ook wel 'representationeel conflict' genoemd – voor twijfel in het taalsysteem. Deze twijfel ontstaat doordat het conflict in de taalwaarneming twee verschillende oorzaken kan hebben: het onverwachte element kan daadwerkelijk zijn opgetreden of het is het gevolg van een perceptuele fout. Stelt u zich bijvoorbeeld voor dat u de volgende zin in de krant leest: 'De man bijt de hond'. Het is zeer waarschijnlijk dat u even stopt met lezen en u zich afvraagt: 'Heb ik dat wel goed gelezen?'. Dit komt doordat de betekenis van de woorden in de zin (man-bijten-hond) de verwachting oproept dat de hond de man bijt en niet andersom. De interpretatie die ontstaat vanuit onze zogenoemde 'kennis van de wereld' (de hond bijt de man) is daardoor in conflict met de interpretatie die voortkomt uit de grammaticale analyse van de zin (de man bijt de hond). Volgens de monitoringtheorie van de taalwaarneming leidt een dergelijk conflict ertoe dat we de zin opnieuw verwerken om na te gaan of we geen verwerkingsfout hebben gemaakt. De theorie veronderstelt dat dit monitoringproces, waarbij een conflict tussen een verwachte en geobserveerde representatie tot herverwerking leidt, weerspiegeld wordt in het P600 effect in het elektro-encefalogram (EEG: zie Box 1).

De monitoringtheorie van de taalwaarneming staat centraal in dit proefschrift, waarbij de focus ligt op monitoring in de visuele perceptie (d.w.z. niet gesproken, maar geschreven tekst). Het is belangrijk hierbij in gedachten te houden dat wij in onze studies niet daadwerkelijke perceptuele fouten – zoals het verkeerd lezen van een woord – hebben onderzocht. In plaats daarvan hebben we dit soort fouten nagebootst door verschillende soorten fouten in het gebruikte stimulusmateriaal te verwerken. Hierbij gaan we ervan uit dat zowel perceptuele fouten, als de aangeboden fouten in ons materiaal, resulteren in eenzelfde soort conflict tussen een verwacht en een geobserveerd linguïstisch element. Op deze manier hebben we de consequenties van fouten in de taalwaarneming nagebootst en onderzocht hoe het taalsysteem hiermee omgaat.

Hoofdonderwerpen in dit proefschrift

In de experimentele studies die worden beschreven in dit proefschrift komen drie belangrijke kwesties aan de orde. Ten eerste onderzochten we in twee event-related potential (ERP: zie Box 1) experimenten of de sterkte van het conflict tussen een verwacht en een geobserveerd element het monitoringproces kan beïnvloeden (Hoofdstuk 3 en 4). Ten tweede onderzochten we in twee functionele magnetic resonance imaging (fMRI: zie Box 2) experimenten het mechanisme in de hersenen dat betrokken is bij het monitoren voor conflicten, waarbij we specifiek geïnteresseerd waren in de rol van het gebied van Broca (Hoofdstuk 4 en 5). Ten derde hebben we in een ERP- en een fMRI-experiment een andere situatie onderzocht die het taalbegrip kan hinderen, namelijk een gebrek aan visuele informatie door stimulusdegradatie. Hierbij hebben we bekeken of een gebrek aan visuele informatie, net als een representationeel conflict, zou leiden tot een monitoringrespons (Hoofdstuk 5 en 6). In het onderstaande zal ik deze drie kwesties en onze bevindingen kort toelichten.

Manipulatie van conflict sterkte

In eerdere ERP-studies die de monitoringtheorie van de taalwaarneming onderzochten, werden condities waarin een conflict tussen een verwacht en een geobserveerd element aanwezig was, vergeleken met condities zonder conflict. In het dagelijks leven zijn conflicten echter meestal niet zo eenduidig. Enerzijds komen we soms informatie tegen die erg onverwacht is. In een dergelijke situatie kan het zinvol zijn om niet meteen te vertrouwen op wat we gelezen hebben, omdat dit kan leiden tot het integreren van foutieve informatie. In plaats daarvan is het beter om eerst te controleren of we mogelijk een verwerkingsfout hebben gemaakt. Anderzijds is het ook vaak het geval dat we informatie tegenkomen die enigszins onverwacht is, bijvoorbeeld wanneer we de krant lezen. Hoewel deze informatie relatief onverwacht is, kan het belangrijke nieuwe informatie zijn waar we iets van kunnen leren. Deze twee voorbeelden geven aan dat niet elk conflict tussen een verwacht en een geobserveerd element hoeft te leiden tot herverwerking. Het zou niet efficiënt zijn wanneer dit wel het geval zou zijn, omdat we dan constant aan onszelf zouden twijfelen (‘Heb ik dat wel goed gelezen?’). Onze hypothese was dan ook dat alleen sterke conflicten, die een bepaalde drempelwaarde overschrijden, herverwerking teweegbrengen. Als deze hypothese juist is, betekent dit dat conflictsterkte van invloed zou kunnen zijn op de ERP-resultaten: niet elk conflict zou dan een(zelfde) P600-effect hoeven te genereren.

Om deze hypothese te onderzoeken, hebben we twee ERP-experimenten uitgevoerd waarin we conflictsterkte manipuleerden. In Hoofdstuk 3 manipuleerden we conflictsterkte als volgt. De proefpersonen lazen zinnen die een sterke verwachting creëerden voor een woord behorende tot een bepaalde categorie. Het daadwerkelijk gepresenteerde kritische woord kon echter variëren in plausibiliteit. Het kritische woord kon namelijk plausibel zijn, en daarmee in overeenstemming met de verwachting, maar het kon ook enigszins implausibel of heel erg implausibel zijn. De volgende zin is een voorbeeld (het kritische woord is onderstreept en de proefpersonen zagen of het plausibele/enigszins implausibele/ heel erg implausibele kritische woord):

(1) Het oog bestaande uit onder andere een pupil, iris en netvlies/wenkbrauw/sticker …

Onze voorspelling was dat alleen in het geval van de heel erg implausibele conditie het conflict tussen de verwachte en de geobserveerde representatie sterk genoeg zou zijn om herverwerking te veroorzaken en een P600-effect te genereren. Voor de enigszins implausibele conditie daarentegen zou het conflict niet sterk genoeg zijn om de drempelwaarde te overschrijden. In dit geval is het kritische woord semantisch gezien meer gerelateerd aan de verwachting. De proefpersonen zouden dan mogelijk toch proberen om de onverwachte informatie te integreren, wat gereflecteerd zou kunnen worden in een N400-effect in het EEG. De ERP-resultaten kwamen overeen met onze voorspellingen: vergeleken met de plausibele conditie was er voor de enigszins implausibele conditie een N400-effect te zien, terwijl de erg implausibele conditie zowel een N400- als een P600-effect teweegbracht. Een verklaring voor het feit dat beide condities een N400-effect genereerden is dat zowel de enigszins implausibele als de heel erg implausibele conditie zorgden voor problemen met de integratie van het kritische woord in de zin. Deze problemen konden waarschijnlijk worden opgelost in het geval van de enigszins implausibele conditie. In het geval van de heel erg implausibele conditie was integratie uiteindelijk niet mogelijk en werd de input herverwerkt voor mogelijke verwerkingsfouten, wat leidde tot een P600-effect. Uit deze ERP-resultaten

Box 1: Event-related potentials

Event-related potentials (ERPs) zijn elektrofysiologische hersenpotentialen die gerelateerd zijn aan een bepaalde gebeurtenis. ERPs kunnen worden afgeleid uit het elektro-encefalogram (EEG). Het EEG toont de elektrische hersenactiviteit, die gemeten kan worden door elektroden op de hoofdhuid te plaatsen. Het ruwe EEG signaal bevat de activiteit van honderden verschillende hersenprocessen. Hierdoor is het moeilijk om de respons van de hersenen op een specifieke gebeurtenis – zoals een bepaalde cognitieve, sensorische of motorische gebeurtenis – in het ruwe EEG signaal te identificeren. Het is echter wel mogelijk om deze ERPs zichtbaar te maken uit het ruwe EEG. Om de ERPs zichtbaar te maken, worden kleine segmenten waarin de gebeurtenis optreedt uit het EEG geknipt. Door een groot aantal van deze segmenten te middelen, valt de elektrische activiteit die niet gerelateerd is aan de gebeurtenis weg, en blijft alleen de activiteit die gerelateerd is aan de gebeurtenis over. In de ERP-studies in dit proefschrift bevatten de segmenten altijd de visuele presentatie van een kritisch woord: de segmenten beginnen 100 ms voorafgaande aan de presentatie van het kritisch woord en eindigen 1000 ms erna.

Het resultaat van het middelen van segmenten, dat voor iedere proefpersoon apart wordt gedaan, is een gemiddeld ERP-signaal dat bestaat uit een aantal opeenvolgende pieken met een positief of negatief voltage – ook wel ERP-componenten genoemd. Bij het labelen van deze componenten verwijst men vaak naar de polariteit ('P' voor positief, 'N' voor negatief) en latentie (in ms), of de ordinale positie van een component in het ERP-signaal. De eerste positieve piek in het ERP-signaal ontstaat bijvoorbeeld over het algemeen rond 100 ms na de presentatie van een visuele stimulus. Deze piek wordt ook wel de P100 genoemd (om de latentietijd aan te duiden) of de P1 (om de ordinale positie aan te duiden). Twee andere kenmerken die ook gebruikt kunnen worden om ERP-componenten te labelen zijn de verdelingen van componenten over de schedel (bijv., ELAN: Early Left Anterior Negativity) en de gevoeligheid van een component voor een bepaald aspect van een taak (bijv., ERN: Error Related Negativity).

Een taalgerelateerde ERP-component die van belang is voor dit proefschrift is de P600. De P600 heeft een positieve amplitude en ontstaat meestal rond 500 ms en duurt voort tot ten minste 800 ms na het aanbieden van een kritisch woord. Meestal heeft de P600 een centraal-posterieure schedelverdeling. Aangezien verschillende soorten syntactische schendingen en syntactisch complexe en ambigue zinnen tot een positievere P600 amplitude leiden, dacht men dat deze component syntactische verwerking weerspiegelde – zie echter Hoofdstuk 2 voor de monitoringtheorie die in dit proefschrift wordt verondersteld. Een andere taalrelevante component is de N400. De N400 heeft een negatieve amplitude en piekt rond 400 ms na aanbieding van het kritische woord. De N400 is breed verdeeld over de schedel, maar meestal negatiever over centrale en parietale elektroden en sterker over de rechter hemisfeer. In tegenstelling tot de P600 gaat men ervan uit dat de N400 semantische verwerking weerspiegelt, aangezien verschillende semantische schendingen zorgen voor een negatievere N400 amplitude.

De ERP-techniek is een waardevolle onderzoeksmethode. Hoewel het minder goed kan identificeren waar in het brein bepaalde cognitieve processen zich afspelen, kan het wel temporele informatie van cognitieve processen tot op de milliseconde nauwkeurig verschaffen.

kunnen we concluderen dat een sterk conflict nodig is om herverwerking te veroorzaken.

In het ERP-experiment in Hoofdstuk 4 manipuleerden we conflictsterkte op een andere manier. In dit experiment varieerden we de verwachting op basis van de zinscontext, terwijl de schending op het kritische woord hetzelfde bleef. De proefpersonen lazen zinnen met daarin spelfouten, zogenaamde ‘pseudohomofonen’, die een incorrecte spelling hebben maar qua fonologie overeenkomen met het correct gespelde woord. Deze spelfouten konden in twee soorten zinscontexten voorkomen, namelijk zinscontexten die een sterke verwachting voor een bepaald woord oproepen of zinscontexten die geen specifieke verwachting oproepen. Bijvoorbeeld:

(2) De kussens zijn opgevuld met verun ... (sterke verwachting)

(3) Op die plek liggen soms verun … (geen specifieke verwachting)

We veronderstelden dat spelfouten in zinscontexten met een sterke verwachting een sterker conflict tussen een verwacht en een geobserveerd element zouden veroorzaken. Deze zinnen creëren namelijk een sterke voorspelling voor een bepaald woord (bijvoorbeeld ‘veren’), terwijl het woord dat de proefpersoon dan leest niet correct gespeld is. Spelfouten in zinscontexten die geen specifieke verwachting genereren, zouden een minder sterk conflict tot gevolg moeten hebben, aangezien er niet een specifieke voorspelling voor een bepaald woord is waarmee de spelfout dan in conflict is. Op basis van deze hypotheses voorspelden we dan ook een groter P600-effect voor de spelfouten in zinscontexten met een sterke verwachting dan spelfouten in zinscontexten zonder specifieke verwachting. Het experiment bevatte ook nog een tweede conditie die een conflict tussen een verwacht en een geobserveerd element opriep, namelijk zinnen met daarin grammaticale fouten op het werkwoord. Bijvoorbeeld:

(4) De schone kleren en handdoeken hangt …

Voor grammaticale fouten wordt standaard een P600-effect gevonden (zie Box 1), wat ons de mogelijkheid gaf om deze P600 te vergelijken met de ERP-respons voor spelfouten. Uit de resultaten bleek dat de spelfouten in beide zinscontexten een P600 genereerden vergeleken met correct gespelde woorden. Dit P600-effect had eenzelfde tijdsverdeling en schedeldistributie als het P600 effect voor grammaticale fouten.

Tevens werd het P600-effect in het geval van de spelfouten gemoduleerd door de conflictsterkte manipulatie: het P600 effect was groter voor spelfouten in zinscontexten die een sterke verwachting voor een bepaald woord opriepen dan het P600 effect voor spelfouten in zinscontexten die geen specifieke verwachting opriepen. Er was echter ook in het geval van spelfouten in zinscontexten zonder specifieke verwachting een P600-effect. Het zou kunnen dat, doordat we pseudohomofonen gebruikten, de woordcontext zelf ook een bepaalde woordverwachting creëerde die in conflict was met de incorrecte spelling van het kritische woord. Concluderend kan gezegd worden dat, net als de resultaten van het ERP-experiment in Hoofdstuk 3, de resultaten in Hoofdstuk 4 de hypothese ondersteunen dat conflictsterkte van invloed kan zijn op het P600-effect.

Mechanisme in de hersenen betrokken bij het monitoren voor conflicten

Een tweede belangrijke kwestie die werd onderzocht in dit proefschrift is het mechanisme in de hersenen dat betrokken is bij het monitoren voor conflicten in de visuele taalwaarneming. Hierbij waren we specifiek geïnteresseerd in een bepaald deel van de prefrontale cortex, namelijk het posterieure gedeelte van de linker inferieure frontale gyrus (lIFG) (Brodmann gebied (BA) 44 en 45). Binnen het taalonderzoek staat dit gebied ook wel bekend als het gebied van Broca. Op basis van verscheidene studies waarin onderzoek werd gedaan naar zinsverwerking, wordt aangenomen dat activiteit in het gebied van Broca syntactische verwerking weerspiegelt. Het gebied wordt bijvoorbeeld actiever bij het lezen van syntactisch ambigue zinnen, die ons om de tuin leiden, zoals: 'Experimenten met regen maken lijken succesvol' (waar *lijken* gelezen kan worden als een zelfstandig naamwoord, of als een werkwoord). Uit de cognitieve controle literatuur blijkt echter ook dat de lIFG betrokken is bij taken die geen syntactische of zelfs taal-specifieke verwerking vereisen. Een voorbeeld hiervan is de Stroop-taak. In deze cognitieve controle taak die gebruikt wordt om representationele conflicten te onderzoeken, moeten proefpersonen de inktkleur van een geschreven woord benoemen. In het geval van incongruente trials is er sprake van een conflict, omdat de inktkleur niet overeenkomt met het geschreven woord dat ook een kleur aanduidt (bijvoorbeeld het woord *groen* gedrukt in blauwe inkt). De lIFG laat een verhoogde activiteit zien voor deze incongruente trials. Om deze bevindingen te verenigen met onderzoeken binnen het taaldomein veronderstelden Novick e.a. (2005) dat de lIFG algemener betrokken is bij het oplossen van representationele conflicten. Het idee is dat in het geval van een conflict tussen verschillende representaties de lIFG de controleprocessen zodanig aanstuurt dat één van de representaties versterkt wordt. In het geval van de Stroop-taak krijgt de relevante informatie (de inktkleur) hierdoor meer aandacht, terwijl de automatische respons (het lezen van het woord) wordt tegengegaan. In het geval van syntactisch ambigue zinnen wordt de minder geprefereerde correcte analyse van de zin versterkt en de automatische incorrecte analyse tegengegaan. Ter ondersteuning van dit voorstel van Novick e.a. (2005) vonden January e.a. (2009) voor dezelfde groep proefpersonen inderdaad dat de incongruente trials in de Stroop-taak en syntactisch ambigue zinnen beide zorgden voor een verhoogde lIFG-activatie.

Box 2: Functional Magnetic Resonance Imaging

Functional Magnetic Resonance Imaging (fMRI) is een beeldvormende techniek waarbij gebruik wordt gemaakt van magnetische resonantie om cognitieve processen in het brein te lokaliseren. Wanneer een bepaald hersengebied actiever wordt, zorgt dit voor een toename in zuurstofgebruik in dat gebied. Deze toename in zuurstofgebruik gaat gepaard met een sterkere doorbloeding in het actieve gebied in de hersenen. In dit proces richt de fMRI-meting zich op de magnetische eigenschappen van hemoglobine, een eiwit in de rode bloedcellen dat zuurstof door de bloedvaten transporteert. Door de sterkere doorbloeding in het actieve gebied neemt ook het gehalte van zuurstofrijk hemoglobine toe. Deze toename zorgt voor veranderingen in de magnetische eigenschappen van het bloed, wat weerspiegeld wordt in het fMRI-signaal. Dit zogenaamde Blood-Oxygenation-Level Dependent (BOLD) signaal is daarom een indirecte meting van de activiteit die het gevolg is van mentale processen.

In tegenstelling tot ERP-metingen (zie Box 1) heeft fMRI een hoge spatiële resolutie (2-3 mm). Om deze reden is fMRI een waardevolle methode om te onderzoeken waar in het brein bepaalde cognitieve processen zich afspelen. fMRI heeft echter een lage temporele resolutie, omdat de piek van het BOLD signaal een vertraging heeft van 4-6 seconden na de neurale activatie.

In het fMRI-experiment in Hoofdstuk 4 hebben we onderzocht of dit voorstel voor de lIFG ook toegepast kan worden op het verwerken van fouten in de visuele taalwaarneming. De monitoringtheorie van de taalwaarneming veronderstelt immers dat perceptuele fouten kunnen leiden tot een representationeel conflict. De vraag was dan ook of verschillende soorten taalfouten ook een verhoogde lIFG-activatie laten zien. We onderzochten dit door proefpersonen zowel zinnen met grammaticale fouten (zie voorbeeld (4)) als zinnen met spelfouten (zie voorbeeld (2) en (3)) te laten lezen in de MRI-scanner. De resultaten lieten inderdaad zien dat zowel de grammaticale fouten als de spelfouten een verhoogde activatie teweegbrachten, vergeleken met correcte zinnen in een overlappend lIFG-gebied. Het voorstel van Novick e.a. (2005) dat de lIFG betrokken is bij het oplossen van representationele conflicten kan hiermee worden uitgebreid naar fouten in de taalwaarneming. Tevens ondersteunen de resultaten het voorstel dat de representationele conflicten niet per se syntactisch van aard hoeven te zijn om de lIFG te activeren.

In het fMRI-experiment in Hoofdstuk 5 onderzochten we of het oplossen van conflicten die ontstaan door fouten in de taalwaarneming en door incongruente trials in de Stroop-taak de activatie verhogen in hetzelfde lIFG gebied. In dit experiment lazen de proefpersonen zowel zinnen met grammaticale fouten (zie voorbeeld (4)) als zinnen met schendingen van plausibiliteit (zie voorbeeld (1)). Ook deden de proefpersonen mee aan een Stroop-taak, om het gedeelte van de lIFG te bepalen (BA 44/45), dat een verhoogde activatie laat zien voor de incongruente trials. Op basis van het voorstel dat de lIFG meer algemeen betrokken is bij het oplossen van representationele conflicten voorspelden we dat zowel de grammaticale als de plausibiliteit schendingen verhoogde activatie zouden laten zien in hetzelfde lIFG-gebied als de Stroop-taak. De resultaten kwamen overeen met deze voorspelling en zijn daarmee een verdere ondersteuning van het voorstel van Novick e.a. (2005).

Monitoringrespons bij een gebrek aan informatie

Een derde kwestie die in dit proefschrift aan de orde werd gesteld, was de vraag of een gebrek aan visuele informatie ook zou kunnen leiden tot een monitoringrespons. De gedachte hierachter was dat ons taalbegrip niet alleen verstoord kan worden door conflicten tussen verwachte en geobserveerde elementen. Ook woorden die moeilijk leesbaar zijn, kunnen ons taalbegrip verstoren en daarmee een aanleiding zijn voor extra aandacht. Om een dergelijke situatie te onderzoeken, creëerden we een visuele degradatieconditie. Deze conditie bevatte de zinscontexten uit Hoofdstuk 4 die geen specifieke verwachting voor een bepaald woord opriepen (zie voorbeeld (3)). Het kritische woord was nu echter altijd correct gespeld. We veronderstelden dat er in dit geval geen representationeel conflict zou ontstaan, aangezien er geen verwachting voor een bepaald element werd gecreëerd en het kritische woord geen schending bevatte. Wat we daarentegen wel manipuleerden, was de leesbaarheid van het kritische woord: het woord was normaal leesbaar, of het was visueel gedegradeerd door at random 75% van de pixels uit het woord te verwijderen.

In Hoofdstuk 5 onderzochten we deze visuele degradatieconditie in hetzelfde fMRI-experiment als hierboven beschreven. Naast grammaticale en plausibiliteit schendingen en een Stroop-taak bevatte het experiment namelijk ook een visuele degradatieconditie. We veronderstelden dat als deze visuele degradatieconditie ook een verhoogde activatie in hetzelfde lIFG-gebied als de Stroop-taak zou veroorzaken, dit zou kunnen betekenen dat de lIFG niet alleen betrokken is bij het oplossen van representationele conflicten, maar ook een rol speelt wanneer een gebrek aan visuele informatie gecompenseerd moet worden. De resultaten lieten ook voor de visuele degradatieconditie een verhoogde activatie zien in hetzelfde lIFG-gebied als de andere condities. Dit resultaat kan erop wijzen dat de lIFG, naast het richten van de aandacht om representationele conflicten op te lossen, ook van belang is bij het sturen van de aandacht wanneer een gebrek aan informatie in de visuele taalwaarneming gecompenseerd moet worden.

In Hoofdstuk 6 onderzochten we dezelfde visuele degradatieconditie in een EEG-experiment. We vergeleken de ERP-respons voor de visuele degradatieconditie met de ERP-respons voor twee soorten representationele conflicten (grammaticale en plausibiliteit schendingen) binnen dezelfde proefpersonen. Onze hypothese was dat als er op eenzelfde manier met beide situaties wordt omgegaan, de visuele degradatie conditie ook een positiviteit in het P600 tijdsvenster zou moeten laten zien, net als de twee soorten schendingen die een representationeel conflict oproepen. De resultaten lieten een centraal-posterieur verdeelde positiviteit zien tussen 300-800 ms voor de gedegradeerde conditie vergeleken met de niet-gedegradeerde conditie. Dit tijdsbestek bevat het tijdsvenster waarin over het algemeen een P600-effect wordt gevonden. Ook de centraal-posterieure schedelverdeling komt overeen met de distributie die vaak voor het P600-effect wordt gerapporteerd. Uit de resultaten bleek echter wel enige variatie wat betreft het tijdsvenster en de schedelverdeling van de positiviteiten die werden gevonden voor de gedegradeerde conditie (300-800 ms, centraal-posterieure schedelverdeling), de grammaticale schendingen (550-800 ms, brede schedelverdeling) en de heel erg implausibele conditie (700-1000 ms, vooral links centraal-posterieure schedelverdeling). We veronderstellen dat een algemeen monitoringproces ten grondslag zou kunnen liggen aan deze positiviteiten. Zowel representationele conflicten als een gebrek aan informatie kunnen het taalbegrip verstoren en zorgen voor twijfel in het systeem. Beide probleemsituaties geven daarmee aan dat er aanpassingen in de controleprocessen nodig zijn om na te gaan of er mogelijk een verwerkingsfout is gemaakt of om het correcte woord te kunnen identificeren. De variatie in de tijdsvensters en schedeldistributie van de positiviteiten zou kunnen duiden op een verschil in de soort en complexiteit van de informatie die het taalbegrip verstoort en die moet worden herverwerkt of geïdentificeerd.

Conclusie

In dit proefschrift heb ik verder onderzoek gedaan naar monitoring in de visuele taalwaarneming. Wat de beschreven experimenten aantonen, is ten eerste dat het monitoringproces, zoals weerspiegeld in het P600 effect, wordt beïnvloed door de sterkte van het conflict tussen een verwacht en een geobserveerd linguïstisch element. Ten tweede heb ik laten zien dat een belangrijk gebied voor cognitieve controle – de lIFG – betrokken is bij dit monitoringproces voor verschillende soorten taalfouten. Dit sluit aan bij het idee dat de lIFG meer algemeen betrokken is bij het oplossen van representationele conflicten. Ten derde heb ik laten zien dat niet alleen een representationeel conflict, maar ook een gebrek aan informatie in de visuele taalwaarneming kan leiden tot een monitoringrespons. Dit wordt weerspiegeld in de gevonden positiviteiten in het EEG en de verhoogde lIFG-activatie. De studies die in dit proefschrift zijn beschreven, onderschrijven daarmee het belang van het cognitieve controleproces van monitoren in de visuele taalwaarneming. Om beter te begrijpen hoe ons taalsysteem omgaat met situaties die twijfel oproepen, is het belangrijk dat we ons realiseren dat taalprocessen niet op zichzelf staan maar voortdurend interacteren met andere cognitieve processen.

Dankwoord

Tijd is oneindig en niet in woorden te vatten… Toch zal ik proberen op de komende pagina’s iedereen te noemen die de afgelopen 4 jaar belangrijk is geweest om mijn promotietraject tot een goed einde te brengen.

Als eerste wil ik mijn promotoren en copromotoren bedanken. Herman, jouw aanstekelijke enthousiasme en onze kritische discussies zijn van onschatbare waarde geweest voor mijn ontwikkeling als onderzoekster en hebben een belangrijke bijdrage geleverd aan dit proefschrift. Hoewel je al met emeritaat was, bleef je altijd nauw betrokken. Zelfs wanneer ik dacht dat de omstandigheden het niet toelieten, kon ik altijd op je begeleiding rekenen. Ik hoop dat ondanks dat ik je laatste promovenda ben, je de wetenschapswereld blijft inspireren. Dorothee, je leerde me kritisch naar mijn ERP data te kijken en deze helder te verwoorden. Daarnaast stimuleerde je mijn zelfvertrouwen door me aan te moedigen congressen te bezoeken, praatjes te geven en contact te leggen met en me voor te stellen aan collega wetenschappers. Bedankt voor je geloof in mij. Peter and Shirley-Ann, thank you for guiding me through the world of fMRI research. With your critical attitudes and focus on the data you have promoted valuable theoretical reflections, for which I am very grateful.

Ook de leden van de manuscriptcommissie, Herbert Schriefers, Gina Kuperberg en Richard Ridderinkhof wil ik bedanken voor het zorgvuldig doorlezen van mijn manuscript. Especially Gina, thank you for the interesting discussions about our research and for showing me your lab and research group.

Dan de personen die mij het meest hebben meegemaakt op het DCC: mijn kamergenoten. Yvonne, door jouw open en directe houding voelde ik me meteen welkom op mijn eerste werkdag. We hebben samen veel gelachen, maar ook wat tranen gelaten in moeilijkere tijden. Onze persoonlijke gesprekken gaven mij lucht. Bedankt voor je steun en luisterend oor. Ook onze treinreizen samen met Sabine richting Den Bosch zal ik niet snel vergeten, met rond Oss de knorrende vraag: “Wat eten jullie vanavond?”. Sara, als mede-taalsectiegenoot hebben we heel wat leuke en interessante discussies gevoerd over onze experimenten en resultaten. Je liep een jaar op me voor en zo heb ik mooi de kunst kunnen afkijken hoe het promotietraject tot een goed einde te brengen. Sebo, jij was mijn laatste kamergenoot op het DCC en hebt me meegemaakt richting het einde van mijn project. Soms was het even nodig de grizzlyberen op de weg te ontwijken en in plaats daarvan schattige wasbeertjes tegemoet te treden. Onze (neuro)filosofische discussies, persoonlijke gesprekken, fruit- en theemomentjes (Xi Hu Long Jing & Genmaicha – ja ik heb het onthouden!) en jouw muziekintermezzo's en kookpassie hebben me daarbij geholpen. Ik vind het dan ook erg fijn dat jij me bij mijn verdediging als paranimf zult bijstaan.

Naast mijn kamergenoten wil ik natuurlijk ook alle andere (ex-)collega's van het Donders Instituut bedanken voor de goede werksfeer en leuke activiteiten! Het volleyballen, de koffiepauzes, lunchwandelingen en sinterklaasavonden waren altijd erg gezellig en een welkome afleiding. Het wordt een oneindige lijst om iedereen bij naam te noemen, daarom licht ik er een aantal uit. Constance V., bedankt dat je mij als stagiaire onder je hoede hebt genomen en ik vond het altijd erg interessant om samen te brainstormen over onderzoek en toekomst. Sybrine, bedankt voor je enthousiasme en je volhardende geklop op de deur van mijn kamer om me mee te nemen richting lunch! Carmen, thank you for our motivating discussions and for showing me Montréal. Sophie, hoewel het soms beladen gesprekken waren, heb ik genoten van onze koffie/chocomomenten. Jeroen, bedankt voor het oplossen van al mijn Matlab problemen en de daarna welverdiende koffiepauzes. Kirsten, thank you for always answering my questions concerning my fMRI experiments and analyses. Femke, bedankt voor je wijze raad zo aan het einde van mijn project. Miriam, erg leuk vond ik het om onze UNIMO bijeenkomsten af en toe samen voort te zetten, kritisch te discussiëren en samen te brainstormen over onze theorieën en data. Inge, Mathieu en Ardi, bedankt dat jullie mij de mogelijkheden hebben geboden om onderwijservaring op te doen en zo mijn onderwijsaantekening te behalen. Zonder goede onderzoeksomstandigheden en ondersteuning had ik mijn promotietraject niet kunnen doorlopen. Daarom Yvonne, Saskia, Moniek, Johanna, Maaike en Jolanda bedankt voor al jullie hulp. Ook de technische mannen, Jos, Hubert, Pascal, Gerard, André en Paul, bedankt voor het oplossen van al mijn computerproblemen en jullie hulp bij het realiseren van mijn EEG en fMRI experimenten. Gaby, thank you for helping me with my last EEG experiment, and thank you for your cheerfulness!

Ook ontspanning buiten de onderzoekswereld heeft bijgedragen aan de totstandkoming van dit proefschrift. Alle meiden/trainers/coaches van Kidang D3 en Spirit D2: heerlijk dat ik de (soms hoog opgelopen) frustraties eruit heb mogen rammen. Onze wekelijkse trainingen, wedstrijden en gezelligheid zijn een goede uitlaatklep:

boem-tjakka! Natuurlijk ook de Tonnen plus aanhang: Ralph & Marije, Thomas & Karlijn, Mathijs & Serena, Thomas & Rosanne, Tinka & Laurens, Eric, Sylvie en Ann. Bedankt voor de gezellige avonden, weekenden in de Ardennen, jaarwisselingen en ski-reizen. Marinel, samen zijn we aan het fotograferen geslagen en ik vind het dan ook geweldig dat jij mijn verdediging gaat vastleggen op de gevoelige plaat. Onze vaste Photoshop/eetafspraken – waar soms geen computer meer aan te pas komt – vormen een welkome onderbreking van mijn soms doordenderende gedachten. Constance H., samen waren we student-assistent op het MPI en dit is uitgegroeid tot een hechte vriendschap. Tussen ons werk door even koffie drinken op de HAN of op de uni, samen eten en kletsen over vanalles, vooral ook over onze kleine neefjes! Als het goed is zullen we dit jaar ongeveer tegelijk klaar zijn met onze extra studies/stages – zullen we samen nog maar een afstudeerfeestje geven? Sonnie, je bent me bijna altijd telefonisch voor om te informeren hoe het met alles gaat en om een afspraak te maken voor onze terugkerende kaasfondues! Erg ontspannend is het ook om samen te fantaseren over verre reisbestemmingen; Afrika, Azië, of toch… Boukje, samen zijn we begonnen bij Pedagogiek en uiteindelijk allebei andere richtingen opgegaan, zonder elkaar uit het oog te verliezen. Onze gezamenlijke wandelingen, ook met de mannen en sinds kort met Anne, waren heerlijke uitstapjes voor een fris en helder hoofd.

Odilia, mijn grote kleine vriendin… Voor jou een aparte alinea. We gaan al heel wat jaren terug samen en delen lief en leed. Ik ben ontzettend blij dat jij mijn vriendin bent. Onze etentjes, relaxdagen en weekenden zijn altijd om naar uit te kijken. Ook onze gesprekken tot in de late uurtjes zorgen ervoor dat alles weer in perspectief wordt geplaatst. En trots dat we op elkaar zijn! Heel fijn vind ik het dan ook dat jij bij mijn verdediging als paranimf aan mijn zijde staat. En dat we nog maar veel mooie momenten samen mogen meemaken!

Pap en mam, bedankt dat jullie er altijd voor me zijn en me onvoorwaardelijke steun en liefde geven. Jullie hebben het mogelijk gemaakt dat ik ben gekomen waar ik nu ben, en hiervoor ben ik jullie ontzettend dankbaar. Ik kan altijd mijn hart bij jullie luchten en jullie voelen aan wanneer ik behoefte heb aan ontspanning en niet-werkgerelateerde gesprekken. Kim & Vincent, Rik & Roos, Theo, Antoinette en Daisy, ook jullie wil ik bedanken voor jullie steun en interesse. Hoewel het misschien nog steeds niet helemaal duidelijk is wat ik nu precies doe, bleven jullie altijd informeren naar het onderzoek en naar mij. Luuk & Daan, jullie zijn nog veel te klein om hier ook maar iets van te snappen, maar bedankt voor de dikke knuffels en kussen!

En natuurlijk tot besluit, lieve Sander; mijn steun en toeverlaat, mijn rots in de branding. Zonder jou was dit proefschrift er niet geweest. Je bent er altijd voor me, gelooft in me en je geeft me vertrouwen. Bedankt voor je rust, geduldig luisteren, relativeringsvermogen en natuurlijk bedankt voor al je liefde.

Curriculum Vitae

Nan van de Meerendonk werd geboren op 7 april 1984 in Gendt, een klein dorp in de Betuwe. Rond haar negende levensjaar verhuisde zij samen met haar ouders, broer en zus, naar het nabijgelegen Bemmel. Na het behalen van haar Gymnasium diploma in 2001 aan het Stedelijk Gymnasium Nijmegen begon zij aan de studie Pedagogische Wetenschappen en Onderwijskunde aan de Radboud Universiteit Nijmegen. Al in haar eerste studiejaar merkte zij dat haar interesse niet zozeer lag bij het gedrag van kinderen specifiek, maar dat van de mens in het algemeen. Na het behalen van haar Propedeuse Pedagogiek stapte zij dan ook over naar de studie Psychologie. In 2005 ontving zij haar Bachelor diploma en begon, vanwege haar interesse in de verwerking van cognitieve processen in de hersenen, aan de tweejarige onderzoeksmaster Cognitive Neuroscience. Tussen 2005 en 2007 combineerde zij haar studie met een baan als student-assistent op het Max Planck Instituut voor Psycholinguïstiek, en werkte zij als onderwijsmedewerker voor de cursus Toegepaste Onderzoeksmethoden. In 2007 studeerde zij af na een scriptieonderzoek over de verwerking van taalfouten in de hersenen op het Donders Institute for Brain, Cognition and Behaviour te Nijmegen, onder begeleiding van prof. dr. Herman Kolk en dr. Dorothee Chwilla. Dit onderzoek zette zij vanaf 2008 voort als promovenda op het Donders Instituut, onder begeleiding van prof. dr. Herman Kolk, dr. Dorothee Chwilla, prof. dr. dr. Peter Indefrey, en dr. Shirley-Ann Rueschemeyer. De resultaten van dit project staan beschreven in dit proefschrift. Gedurende haar tijd als promovenda heeft Nan tevens onderwijs verzorgd voor verschillende cursussen binnen de opleiding Psychologie, Taalwetenschappen en de Master Cognitive Neuroscience. Vanaf februari 2012 loopt zij een neuropsychologische stage op de afdeling Geriatrie van het UMC St. Radboud in Nijmegen.

Publications

Journal articles

Van de Meerendonk, N., Chwilla, D.J., & Kolk, H.H.J. (under revision). States of indecision in the brain: ERP reflections of representational conflicts and word degradation.

Van de Meerendonk, N., Rueschemeyer, S-A., & Kolk, H.H.J. (submitted). Not only syntactic and semantic anomalies but also word degradation co-localize with the Stroop task in Broca's area.

Van de Meerendonk, N., Indefrey, P., Chwilla, D.J. & Kolk, H.H.J. (2011). Monitoring in language perception: Electrophysiological and hemodynamic responses to spelling violations. *NeuroImage, 54*(3), 2350-2363.

Van de Meerendonk, N., Kolk, H.H.J., Vissers, C.T.W.M., & Chwilla, D.J. (2010). Monitoring in language perception: Mild and strong conflicts elicit different ERP patterns. *Journal of Cognitive Neuroscience, 22(1),* 67-82.

Van de Meerendonk, N., Kolk, H.H.J., Chwilla, D.J., & Vissers, C.T.W.M. (2009). Monitoring in language perception. *Language and Linguistics Compass, 3(5),* 1211-1224.

Vissers, C.T.W.M., Kolk, H.H.J., Van de Meerendonk, N., & Chwilla, D.J. (2008). Monitoring in language perception: Evidence from ERPs in a picture-sentence matching task. *Neuropsychologia, 46*, 967-982.

Conferences

Van de Meerendonk, N., Chwilla, D.J., Rueschemeyer, S-A., & Kolk, H.H.J. (2012). Language comprehension interrupted: ERP and fMRI reflections of representational conflicts and word degradation. *Supplement of the Journal of Cognitive Neuroscience, F63*. Poster presented at the Annual Meeting of Cognitive Neuroscience Society, Chicago, USA.

Van de Meerendonk, N., Rueschemeyer, S-A., & Kolk, H.H.J. (2011). Not only syntactic and semantic anomalies but also word degradation co-localize with the Stroop task in Broca's area. Talk given at the Winter Conference on Cognition, Brain and Behaviour of the Dutch Psychonomic Society, Egmond aan Zee, the Netherlands.

Van de Meerendonk, N. (2011). The P600 and conflict monitoring in language perception. Talk given at the Donders Discussions, Nijmegen, the Netherlands.

Schreuder, R., Van Gorp, K., Van de Meerendonk, N., & Chwilla, D.J. (2011). Differential effects of the transparency of idiomatic adjective-noun combinations on N400. *Supplement of the Journal of Cognitive Neuroscience,* I84. Poster at the Annual Meeting of Cognitive Neuroscience Society, San Francisco, USA.

Van de Meerendonk, N., Indefrey, P., & Kolk, H.H.J. (2010). ERP and fMRI reflections of language monitoring: The case of spelling errors. Poster presented at the 7th FENS forum of European Neuroscience, Amsterdam, the Netherlands.

Van de Meerendonk, N., Indefrey, P., & Kolk, H.H.J. (2010). ERP and fMRI reflections of language monitoring: The case of spelling errors. *Supplement of the Journal of Cognitive Neuroscience,* D13. Poster presented at the Annual Meeting of Cognitive Neuroscience Society, Montréal, Canada.

Van de Meerendonk, N., Indefrey, P., & Kolk, H.H.J. (2009). Monitoring in language perception: Neural correlates of syntactic and spelling violations. Poster presented at the Winter Conference on Cognition, Brain and Behaviour of the Dutch Psychonomic Society, Egmond aan Zee, the Netherlands.

Van de Meerendonk, N., Indefrey, P., & Kolk, H.H.J. (2009). Monitoring in language perception: Neural correlates of syntactic and spelling violations. Poster presented at the Donders Discussions, Nijmegen, the Netherlands.

Van de Meerendonk, N. (2008). Language perception and executive control. Talk given at the Donders Discussions, Nijmegen, the Netherlands.

Van de Meerendonk, N., Vissers, C.T.W.M., Chwilla, D.J., & Kolk, H.H.J (2008). Monitoring in language perception: Mild and strong conflicts elicit different ERP patterns. *Supplement of the Journal of Cognitive Neuroscience,* C124. Poster presented at the Annual Meeting of Cognitive Neuroscience Society, San Francisco, USA.

Van de Meerendonk, N., Vissers, C.T.W.M., Chwilla, D.J., & Kolk, H.H.J. (2007). Monitoring in language perception: Mild and strong conflicts elicit different ERP patterns. Talk given at the Winter Conference on Cognition, Brain and Behaviour of the Dutch Psychonomic Society, Egmond aan Zee, the Netherlands.

Vissers, C.T.W.M., Kolk, H.H.J, Van de Meerendonk, N., Chwilla, D.J. (2007). Monitoring of language perception: P600 effects of sentence-picture mismatches. *Supplement of the Journal of Cognitive Neuroscience,* E41. Poster at the Annual meeting of Cognitive Neuroscience Society, New York, USA.

Donders Graduate School for Cognitive Neuroscience Series

1. van Aalderen-Smeets, S.I. (2007). *Neural dynamics of visual selection.* Maastricht University, Maastricht, the Netherlands.
2. Schoffelen, J.M. (2007). *Neuronal communication through coherence in the human motor system.* Radboud University Nijmegen, Nijmegen, the Netherlands.
3. de Lange, F.P. (2008). *Neural mechanisms of motor imagery.* Radboud University Nijmegen, Nijmegen, the Netherlands.
4. Grol, M.J. (2008). *Parieto-frontal circuitry in visuomotor control. Utrecht* University, Utrecht, the Netherlands.
5. Bauer, M. (2008). *Functional roles of rhythmic neuronal activity in the human visual and somatosensory system.* Radboud University Nijmegen, Nijmegen, the Netherlands.
6. Mazaheri, A. (2008). *The Influence of Ongoing Oscillatory Brain Activity on Evoked Responses and Behaviour*. Radboud University Nijmegen, Nijmegen, the Netherlands.
7. Hooijmans, C.R. (2008). *Impact of nutritional lipids and vascular factors in Alzheimer's Disease.* Radboud University Nijmegen, Nijmegen, the Netherlands.
8. Gaszner, B. (2008). *Plastic responses to stress by the rodent urocortinergic Edinger-Westphal nucleus.* Radboud University Nijmegen, Nijmegen, the Netherlands.
9. Willems, R.M. (2009). *Neural reflections of meaning in gesture, language and action.* Radboud University Nijmegen, Nijmegen, the Netherlands.
10. van Pelt, S. (2009). *Dynamic neural representations of human visuomotor space.* Radboud University Nijmegen, Nijmegen, the Netherlands.
11. Lommertzen, J. (2009). *Visuomotor coupling at different levels of complexity.* Radboud University Nijmegen, Nijmegen, the Netherlands.
12. Poljac, E. (2009). *Dynamics of cognitive control in task switching: Looking beyond the switch cost.* Radboud University Nijmegen, Nijmegen, the Netherlands.
13. Poser, B.A. (2009). *Techniques for BOLD and blood volume weighted fMRI.* Radboud University Nijmegen, Nijmegen, the Netherlands.
14. Baggio, G. (2009). *Semantics and the electrophysiology of meaning. Tense, aspect, event structure*. Radboud University Nijmegen, Nijmegen, the Netherlands.
15. van Wingen, G.A. (2009). *Biological determinants of amygdala functioning*. Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
16. Bakker, M. (2009). *Supraspinal control of walking: lessons from motor imagery.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
17. Aarts, E. (2009). *Resisting temptation: the role of the anterior cingulate cortex in adjusting cognitive control.* Radboud University Nijmegen, Nijmegen, the Netherlands.
18. Prinz, S. (2009). *Waterbath stunning of chickens – Effects of electrical parameters on the electroencephalogram and physical reflexes of broilers.* Radboud University Nijmegen, Nijmegen, the Netherlands.
19. Knippenberg, J.M.J. (2009). *The N150 of the Auditory Evoked Potential from the rat amygdala: In search for its functional significance.* Radboud University Nijmegen, Nijmegen, the Netherlands.

20. Dumont, G.J.H. (2009). *Cognitive and physiological effects of 3,4-methylenedioxymethamphetamine (MDMA or 'ecstasy') in combination with alcohol or cannabis in humans* Radboud University Nijmegen, Nijmegen, the Netherlands.
21. Pijnacker, J. (2010). *Defeasible inference in autism: a behavioral and electrophysiogical approach*. Radboud University Nijmegen, Nijmegen, the Netherlands.
22. de Vrijer, M. (2010). *Multisensory integration in spatial orientation.* Radboud University Nijmegen, Nijmegen, the Netherlands.
23. Vergeer, M. (2010). *Perceptual visibility and appearance: Effects of color and form.* Radboud University Nijmegen, Nijmegen, the Netherlands.
24. Levy, J. (2010). *In Cerebro Unveiling Unconscious Mechanisms during Reading.* Radboud University Nijmegen, Nijmegen, the Netherlands.
25. Treder, M. S. (2010). *Symmetry in (inter)action*. Radboud University Nijmegen, Nijmegen, the Netherlands.
26. Horlings C.G.C. (2010). *A Weak balance; balance and falls in patients with neuromuscular disorders.* Radboud University Nijmegen, Nijmegen, the Netherlands.
27. Snaphaan, L.J.A.E. (2010). *Epidemiology of post-stroke behavioural consequences*. Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
28. Dado – Van Beek, H.E.A. (2010). *The regulation of cerebral perfusion in patients with Alzheimer's disease.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
29. Derks, N.M. (2010). *The role of the non-preganglionic Edinger-Westphal nucleus in sex-dependent stress adaptation in rodents.* Radboud University Nijmegen, Nijmegen, the Netherlands.
30. Wyczesany, M. (2010). *Covariation of mood and brain activity. Integration of subjective self-report data with quantitative EEG measures*. Radboud University Nijmegen, Nijmegen, the Netherlands.
31. Beurze S.M. (2010). *Cortical mechanisms for reach planning.* Radboud University Nijmegen, Nijmegen, the Netherlands.
32. van Dijk, J.P. (2010). *On the Number of Motor Units.* Radboud University Nijmegen, Nijmegen, the Netherlands.
33. Lapatki, B.G. (2010). *The Facial Musculature – Characterization at a Motor Unit Level.* Radboud University Nijmegen, Nijmegen, the Netherlands.
34. Kok, P. (2010). *Word Order and Verb Inflection in Agrammatic Sentence Production.* Radboud University Nijmegen, Nijmegen, the Netherlands.
35. van Elk, M. (2010). *Action semantics: Functional and neural dynamics.* Radboud University Nijmegen, Nijmegen, the Netherlands.
36. Majdandzic, J. (2010). *Cerebral mechanisms of processing action goals in self and others.* Radboud University Nijmegen, Nijmegen, the Netherlands.
37. Snijders, T.M. (2010). *More than words – neural and genetic dynamics of syntactic unification.* Radboud University Nijmegen, Nijmegen, the Netherlands.
38. Grootens, K.P. (2010). *Cognitive dysfunction and effects of antipsychotics in schizophrenia and borderline personality disorder.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
39. Nieuwenhuis, I.L.C. (2010). *Memory consolidation: A process of integration – Converging evidence from MEG, fMRI and behavior.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.

40. Menenti, L.M.E. (2010). *The right language: differential hemispheric contributions to language production and comprehension in context.* Radboud University Nijmegen, Nijmegen, the Netherlands.
41. van Dijk, H.P. (2010). *The state of the brain, how alpha oscillations shape behaviour and event related responses.* Radboud University Nijmegen, Nijmegen, the Netherlands.
42. Meulenbroek, O.V. (2010). *Neural correlates of episodic memory in healthy aging and Alzheimer's disease.* Radboud University Nijmegen, Nijmegen, the Netherlands.
43. Oude Nijhuis, L.B. (2010). *Modulation of human balance reactions.* Radboud University Nijmegen, Nijmegen, the Netherlands.
44. Qin, S. (2010). *Adaptive memory: imaging medial temporal and prefrontal memory systems*. Radboud University Nijmegen, Nijmegen, the Netherlands.
45. Timmer, N.M. (2011). *The interaction of heparan sulfate proteoglycans with the amyloid β protein.* Radboud University Nijmegen, Nijmegen, the Netherlands.
46. Crajé, C. (2011). *(A)typical motor planning and motor imagery.* Radboud University Nijmegen, Nijmegen, the Netherlands.
47. van Grootel, T.J. (2011). *On the role of eye and head position in spatial localisation behaviour.* Radboud University Nijmegen, Nijmegen, the Netherlands.
48. Lamers, M.J.M. (2011). *Levels of selective attention in action planning.* Radboud University Nijmegen, Nijmegen, the Netherlands.
49. Van der Werf, J. (2011). *Cortical oscillatory activity in human visuomotor integration*. Radboud University Nijmegen, Nijmegen, the Netherlands.
50. Scheeringa, R. (2011). *On the relation between oscillatory EEG activity and the BOLD signal.* Radboud University Nijmegen, Nijmegen, the Netherlands.
51. Bögels, S. (2011). *The role of prosody in language comprehension: when prosodic breaks and pitch accents come into play.* Radboud University Nijmegen, Nijmegen, the Netherlands.
52. Ossewaarde, L. (2011). *The mood cycle: hormonal influences on the female brain.* Radboud University Nijmegen, Nijmegen, the Netherlands.
53. Kuribara, M. (2011). *Environment-induced activation and growth of pituitary melanotrope cells of Xenopus laevis.* Radboud University Nijmegen, Nijmegen, the Netherlands.
54. Helmich, R.C.G. (2011). *Cerebral reorganization in Parkinson's disease.* Radboud University Nijmegen, Nijmegen, the Netherlands.
55. Boelen, D. (2011). *Order out of chaos? Assessment and treatment of executive disorders in brain-injured patients*. Radboud University Nijmegen, Nijmegen, the Netherlands.
56. Koopmans, P.J. (2011). *fMRI of cortical layers.* Radboud University Nijmegen, Nijmegen, the Netherlands.
57. van der Linden, M.H. (2011). *Experience-based cortical plasticity in object category representation.* Radboud University Nijmegen, Nijmegen, the Netherlands.
58. Kleine, B.U. (2011). *Motor unit discharges - Physiological and diagnostic studies in ALS.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
59. Paulus, M. (2011). *Development of action perception: Neurocognitive mechanisms underlying children's processing of others' actions.* Radboud University Nijmegen, Nijmegen, the Netherlands.

60. Tieleman, A.A. (2011). *Myotonic dystrophy type 2. A newly diagnosed disease in the Netherlands.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
61. van Leeuwen, T.M. (2011). *'How one can see what is not there': Neural mechanisms of grapheme-colour synaesthesia*. Radboud University Nijmegen, Nijmegen, the Netherlands.
62. van Tilborg, I.A.D.A. (2011). *Procedural learning in cognitively impaired patients and its application in clinical practice.* Radboud University Nijmegen, Nijmegen, the Netherlands.
63. Bruinsma, I.B. (2011). *Amyloidogenic proteins in Alzheimer's disease and Parkinson's disease: interaction with chaperones and inflammation.* Radboud University Nijmegen, Nijmegen, the Netherlands.
64. Voermans, N. (2011). *Neuromuscular features of Ehlers-Danlos syndrome and Marfan syndrome; expanding the phenotype of inherited connective tissue disorders and investigating the role of the extracellular matrix in muscle.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
65. Reelick, M. (2011). *One step at a time. Disentangling the complexity of preventing falls in frail older persons.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
66. Buur, P.F. (2011). *Imaging in motion. Applications of multi-echo fMRI.* Radboud University Nijmegen, Nijmegen, the Netherlands.
67. Schaefer, R.S. (2011). *Measuring the mind's ear: EEG of music imagery.* Radboud University Nijmegen, Nijmegen, the Netherlands.
68. Xu, L. (2011). *The non-preganglionic Edinger-Westphal nucleus: an integration center for energy balance and stress adaptation.* Radboud University Nijmegen, Nijmegen, the Netherlands.
69. Schellekens, A.F.A. (2011). *Gene-environment interaction and intermediate phenotypes in alcohol dependence.* Radboud University Nijmegen, Nijmegen, the Netherlands.
70. van Marle, H.J.F. (2011). *The amygdala on alert: A neuroimaging investigation into amygdala function during acute stress and its aftermath*. Radboud University Nijmegen, Nijmegen, the Netherlands.
71. De Laat, K.F. (2011). *Motor performance in individuals with cerebral small vessel disease: an MRI study.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
72. Mädebach, A. (2011). *Lexical access in speaking: Studies on lexical selection and cascading activation.* Radboud University Nijmegen, Nijmegen, the Netherlands.
73. Poelmans, G.J.V. (2011). *Genes and protein networks for neurodevelopmental disorders.* Radboud University Nijmegen, Nijmegen, the Netherlands.
74. van Norden, A.G.W. (2011). *Cognitive function in elderly individuals with cerebral small vessel disease. An MRI study.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
75. Jansen, E.J.R. (2011). *New insights into V-ATPase functioning: the role of its accessory subunit Ac45 and a novel brain-specific Ac45 paralog*. Radboud University Nijmegen, Nijmegen, the Netherlands.
76. Haaxma, C.A. (2011). *New perspectives on preclinical and early stage Parkinson's disease.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.

77. Haegens, S. (2012). *On the functional role of oscillatory neuronal activity in the somatosensory system.* Radboud University Nijmegen, Nijmegen, the Netherlands.
78. van Barneveld, D.C.P.B.M. (2012). *Integration of exteroceptive and interoceptive cues in spatial localization.* Radboud University Nijmegen, Nijmegen, the Netherlands.
79. Spies, P.E. (2012). *The reflection of Alzheimer disease in CSF.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
80. Helle, M. (2012). *Artery-specific perfusion measurements in the cerebral vasculature by magnetic resonance imaging.* Radboud University Nijmegen, Nijmegen, the Netherlands.
81. Egetemeir, J. (2012). *Neural correlates of real-life joint action.* Radboud University Nijmegen, Nijmegen, the Netherlands.
82. Janssen, L. (2012). *Planning and execution of (bi)manual grasping.* Radboud University Nijmegen, Nijmegen, the Netherlands.
83. Vermeer, S. (2012). *Clinical and genetic characterisation of Autosomal Recessive Cerebellar Ataxias*. Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
84. Vrins, S. (2012). *Shaping object boundaries: contextual effects in infants and adults.* Radboud University Nijmegen, Nijmegen, the Netherlands.
85. Weber, K.M. (2012). *The language learning brain: Evidence from second language and bilingual studies of syntactic processing.* Radboud University Nijmegen, Nijmegen, the Netherlands.
86. Verhagen, L. (2012). *How to grasp a ripe tomato.* Utrecht University, Utrecht, the Netherlands.
87. Nonkes, L.J.P. (2012). *Serotonin transporter gene variance causes individual differences in rat behaviour: for better and for worse.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
88. Joosten-Weyn Banningh, L.W.A. (2012). *Learning to live with Mild Cognitive Impairment: development and evaluation of a psychological intervention for patients with Mild Cognitive Impairment and their significant others*. Radboud University Nijmegen, Nijmegen, the Netherlands.
89. Xiang, HD. (2012). *The language networks of the brain.* Radboud University Nijmegen, Nijmegen, the Netherlands
90. Snijders, A.H. (2012). *Tackling freezing of gait in Parkinson's disease.* Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
91. Rouwette, T.P.H. (2012). *Neuropathic Pain and the Brain - Differential involvement of corticotropin-releasing factor and urocortin 1 in acute and chronic pain processing*. Radboud University Nijmegen, the Netherlands.
92. Van de Meerendonk, N. (2012). *States of indecision in the brain: Electrophysiological and hemodynamic reflections of monitoring in visual language perception.* Radboud University Nijmegen, Nijmegen, the Netherlands

“Nou, dat was het dan. Al is het eigenlijk nooit afgelopen. Alleen de woordenstroom houdt op.”

(Gerrard, 2006)