

Incremental and predictive discourse processing based on causal and concessive discourse markers: ERP studies on German and English

Heiner Drenhaus (drenhaus@coli.uni-saarland.de)
Saarland University, 66123 Saarbrücken Germany

Vera Demberg (vera@coli.uni-saarland.de)
Saarland University, 66123 Saarbrücken Germany

Judith Köhne (judith.koehne@uni-bamberg.de)
Otto-Friedrich-Universität Bamberg, Germany

Francesca Delogu (delogu@coli.uni-saarland.de)
Saarland University, 66123 Saarbrücken Germany

Abstract

There is some evidence for both the hypothesis that discourse connectors facilitate text comprehension and the hypothesis that processing discourse connectors is highly incremental. Less, however, is known about the way in which different discourse connectors help comprehension and whether they can elicit predictions of upcoming contents. In the present ERP studies on German and English we investigated the effect of congruency and connector type (causal / concessive) on the prediction of a target referent (2x2 design). We found a fronto-central positivity for the concessive connector compared to the causal condition and an N400-like effect for the target noun phrase for incongruent compared to congruent conditions. Our results suggest an effect of context-updating at the connector (frontal positivity) and provide evidence for prediction of upcoming content based on the discourse connector.

Keywords: Sentence Processing, ERP, N400; Frontal Positivity, Predictability, Discourse Connectors, Discourse Relations

Introduction

Discourse connectors (such as *therefore*, *however*, *instead*) have been shown to facilitate comprehension, at least when used appropriately (e.g., Millis & Just, 1994). It is, however, less clear in which way different types of discourse connectors help processing and, in particular, whether they elicit predictions of upcoming linguistic material. Existing work on the processing of discourse relations revealed that discourse connectors are rapidly and incrementally integrated with earlier parts of the discourse (e.g., Traxler et al., 1997). Previous research on the processing of discourse relations also suggests that people have some general cognitive biases when processing text, which lead them to more easily infer causal and continuous than, for instance, concessive discourse relations (Murray, 1995; Sanders, 2005; Brehm, 2005). Of particular relevance here is an ERP study by Kuperberg et al. (2011), who found evidence for a default to interpret adjacent sentences as standing in a causal relationship: causally unrelated scenarios induced a larger N400 than intermediately related scenarios which, in turn,

elicited a larger N400 than causally related scenarios. The view that causal and continuous discourse relations are generally expected by comprehenders is also consistent with recent analyses of discourse relation marking in production data: Asr & Demberg (2012) find that causal and continuous discourse relations are less likely to be marked using explicit discourse connectors than other (presumably less expected) discourse relations. This observation is in accordance with the uniform information density hypothesis (Levy & Jaeger, 2007), which holds that optional linguistic elements (like discourse connectors) may be omitted when they do not convey much new information, i.e. when they mark an expected discourse relation. Taken together, these findings lead to the prediction that discourse connectors which signal discontinuity should be more difficult to process because they require a re-interpretation of the discourse relation that was assumed by default.

In the present ERP studies on German and English, we compare the processing of causal versus concessive discourse connectors. Concessive discourse connectors represent an interesting comparison to causal connectors from a theoretical perspective, as they have been argued to represent the same type of relation but to differ in polarity (Louwes, 2001; Sanders et al., 1992), and have sometimes been referred to as “negative causals” (König & Siemund, 2000). Previous work comparing the processing of causals and concessives in the visual world paradigm (Köhne & Demberg, 2013) showed that both causal and concessive discourse markers can be rapidly integrated into on-line comprehension and that processing the concessive leads to a search for alternatives. While the visual world paradigm is useful in revealing predictions during sentence comprehension through visual attention, it does not give much insight into the underlying processes. Köhne and Demberg’s experiment using eye-movements in reading additionally indicates highly incremental processing and prediction in causals. However, no evidence for incremental processing and rapid integration was found for concessives. The authors hypothesize that their results may be due to an increased difficulty of processing concessives, or of integrating them with upcoming content.

The present ERP studies aim to complement these earlier studies by examining a) whether processing concessives is more difficult than processing causals and b) whether readers also predict upcoming linguistic content without the support of a visual scene, both in causal and concessive discourses. Two ERP components are particularly relevant for the present studies: the N400 and a late positive component (P600). The N400, a broadly distributed negative deflection peaking around 400ms post-stimulus onset was initially observed in response to sentence-final semantically incongruent words, but was soon discovered to be part of the normal response to words and other potentially meaningful stimuli (Kutas & Federmeier, 2011). Importantly, the N400 amplitude is sensitive to the predictability of a word in its sentential (e.g., Kutas & Hillyard, 1984) or discourse (e.g., van Berkum et al., 2005) context, with less expected words eliciting larger N400s than more expected words.

The P600, a late positive component with a latency varying between 600 and 900ms, has been traditionally associated with syntactic reanalysis and repair processes (e.g. Osterhout and Holcomb, 1992). More recently, however, late positivities – rather than N400 effects – have been reported to semantic/pragmatic violations (e.g., van Herten et al., 2005; Kuperberg et al., 2003; Drenhaus et al., 2011). Interestingly, the “semantic P600” has been discussed as reflecting the re-organization or updating of the mental representation of the unfolding discourse (Brouwer et al., 2012).

Experiment 1: German

Materials

In the present ERP study on German, we investigated the effect of discourse connector type (causal / concessive) and congruency (congruent/incongruent) on predicting a target referent (2x2 design), see Example (1).

1. *Tim und Kim überlegen, ob sie lieber tanzen gehen oder den neuen Film sehen wollen. Kim findet tanzen toll. Daher/Dennoch gehen sie in die_[fem] frisch renovierte Disko/das_[neut] frisch renovierte Kino, um sich richtig gut zu amüsieren.*
 'Tim and Kim wonder whether they prefer to go dancing or to watch the new movie. Kim likes dancing a lot. Therefore/Nevertheless, they go to the_[fem/neut] newly renovated disco/cinema to enjoy themselves.'

Our stimuli consisted of three-sentence discourses (two context sentences and one target sentence). The first sentence always introduced two alternatives (e.g., going dancing vs. watching a film), the second sentence then identified a preference for one of them (going dancing). The third sentence (i.e., the target sentence) began either with a causal (*deswegen/daher* 'therefore') or a concessive connector (*trotzdem/dennoch* 'however') and included the gender-marked pre-nominal region with an article and an

adjective (*die frisch renovierte/das frisch renovierte*, 'the newly renovated_[fem/neut]'), preceding the target noun (*Disko* 'night club'/*Kino* 'cinema').

We hypothesized that the second sentence together with the discourse marker would elicit predictions about the target noun (e.g. Kim likes dancing + Therefore → night club). Therefore, there should be a mismatch effect (i.e., a larger N400) in both the causal and the concessive condition when the gender of the article in the pre-nominal region does not match the gender of the predicted noun (i.e., in the incongruent condition). Under the assumption that people by default expect causal relations, we further predict a positivity on the concessive connector compared to the causal one, reflecting a discourse model updating process (Brouwer et al. 2012).

Participants

16 undergraduate students (mean age 23, 6 male) from Saarland University participated in this experiment. All participants were native speakers of German and had normal or corrected-to-normal vision. All participants were paid for their participation.

Materials and Procedure

We constructed 96 experimental items (24 per condition, see Examples 1a-d) and 72 unrelated fillers. For the presentation of the stimuli we used the E-prime software (Psychology Software Tools, Inc.). During the experiment, each participant was seated in a sound-proof, electromagnetically shielded chamber. Sentences were presented in black fonts (28-point Times) on a white background.

After a short training session (6 sentences), the 96 experimental items and the 72 fillers were presented in pseudo-randomized order, in 4 blocks with intervening breaks. Each item (and filler) started with two context sentences, which were presented as a whole for 2500ms, followed by a blank screen (150ms), and a fixation star in the center of the screen (500ms). The target sentence was then presented word-by-word in the center of the screen, for 350ms plus 100ms inter-stimulus interval (RSVP).

In 25% of the cases, the target sentence was followed by a plausibility judgment task: participants were asked to press one of two buttons on a response pad within a maximal interval of 2500ms. The EEG was recorded by means of 26 Ag/AgCl scalp electrodes. Electrodes were placed according to the 10-20 system (Sharbrough et al., 1995). Impedances were kept below 5kOhm. The signal was referenced and digitized at a sampling rate of 500 Hz. The EEG raw data were re-referenced to an average of both mastoid electrodes offline. The horizontal electro-oculogram (EOG) was monitored with two electrodes placed at the outer canthus of each eye and the vertical EOG with two electrodes above and below the right eye.

During recording, no on-line filters were used. The EEG data were band-pass filtered offline with 0.1-40Hz. Single-participant averages were computed in a 1000ms window per condition relative to the onset of the critical item and

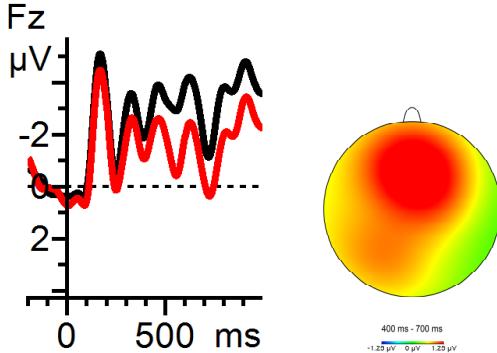


Figure 1: ERP effects at the connector at electrode Fz (left). Negativity is plotted upwards (here and in all other plots). Black line: causal connector condition; red line: concessive connector condition. The scalp distribution of the effect (concessive minus causal) is given on the right side.

aligned to a 200ms pre-stimulus baseline and semi-automatically screened off-line for electrode drifts, amplifier blocking, eye movements, muscle artifacts (4% of data points were excluded). Only artifact-free ERP averages time-locked to the onset of the critical regions entered the analyses (boldfaced in 1a-1d). In our analyses, we compared the critical connector region (causal versus concessive) and each word in the following NP (das/die frisch renovierte Kino/Disko).

Descriptive results (connector)

The ERP patterns to the connectors are displayed in Figs. 1. The concessive connector elicited a larger fronto-central positivity than the causal connector between 400 and 700 ms

Statistical analyses (connector)

We fitted linear mixed models (LMM) (Bates & Sarkar, 2007) with ERP values averaged over critical items for each participant as dependent measure. The fixed factor was the connector type (causal versus concessive). Participants were used as a random factor. Additionally, separate slope terms for participants and connector types were used (the so-called random intercepts and slopes model; Gelman & Hill, 2007). The fronto-centrally distributed positivity in the 400–700ms time-window described above was reliable: The LMM analysis, collapsing over the nine channels (F3, FZ, F4, C3, CZ, C4, P3, PZ, P4), revealed a significant difference ($coefficient = 1.2924$, $SE = 0.3146$, $t = 4.109$).¹ Additionally, we performed baseline analyses for the window 200 to 0ms relative to the onset of the critical word in all reported experiments to make sure that no systematic effects were present prior to presentation of the stimulus ($t <$

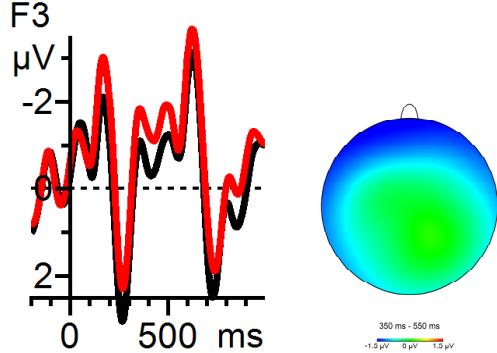


Figure 2: ERP effects on the adjective region following a causal connector at a subset of nine electrodes. Black line: congruent condition; red line: incongruent condition. The scalp distribution of the effect (mismatch minus match) is plotted on the right side.

1). Furthermore, we analyzed the eye electrodes to exclude any interference with experimental effects. The analysis revealed no significant effects in either experiment ($t < 1$). Separate analyses of frontal (F3, FZ, F4), central (C3, CZ, C4), and posterior (P3, PZ, P4) electrode regions of interest (ROIs) revealed a significant effect for the frontal ROI ($coefficient = 1.5645$, $SE = 0.4123$, $t = 3.795$) and the central ROI ($coefficient = 1.1817$, $SE = 0.3510$, $t = 3.367$) but not at the posterior ROI ($t < 1$).

Descriptive results (NP)

Neither visual inspection nor statistical analyses revealed a significant effect at the determiner or the noun. However, at the adjective region (between 350 and 500ms), the incongruent condition elicited a more negative-going ERP than the congruent condition following a causal connector as well as a concessive connector (Fig. 2 and Fig. 3).

Statistical analyses (adjectival region)

We fitted linear mixed models (LMM) with ERP values averaged over critical items for each participant as the dependent measure. Fixed factors were connector type (causal vs. concessive) and congruency (congruent vs. incongruent). Participants were treated as a random factor and also had a separate slope term for connector type (contrast coding: -0.5 for the concessive condition and +0.5 for the causal condition) and congruency (contrast coding: -0.5 for the incongruent condition, and +0.5 for the gender-matching condition). Statistical analyses revealed a more frontally distributed negativity following the causal connector and a more fronto-centrally distributed negativity following the concessive connector for the incongruent condition compared to the congruent condition (Fig. 2 and Fig. 3).

The LMM analysis, collapsing over the nine channels (F3, FZ, F4, C3, CZ, C4, P3, PZ, P4), showed a significant

¹ Following Baayen et al. (2008), t values larger than 2 or smaller than -2 indicate significance at the level of 5%.

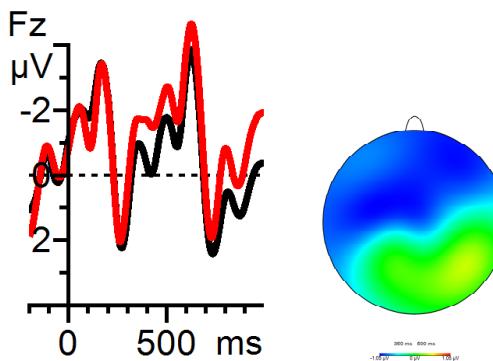


Figure 3: ERP effects on the adjective region following the concessive connector. Black line: congruent condition; red line: incongruent condition. The scalp distribution of the effect (mismatch minus match) is given on the right side.

effect of congruency (*coefficient* = -0.4690, *SE* = 0.2023, *t* = -2.318) but not of connector type (*t* < 1). Separate analyses of frontal, central, and posterior electrode ROIs (regions of interest) showed a significant effect of congruency at the frontal ROI (*coefficient* = -0.9222, *SE* = 0.3709, *t* = -2.486) but no effect of connector type (*t* < 1). No overall effects for connector type or congruency were found at the central (*t* < 1) or posterior (*t* < 1) ROIs.²

Discussion

The ERP analyses revealed a significant fronto-central positivity for processing the concessive connector compared to processing the causal one. This can be interpreted as an effect of context-updating from the expected causal discourse relation to the concessive discourse relation (see general discussion), in line with our predictions.

We furthermore found a frontal N400-like effect on the pre-nominal region for the incongruent compared to the congruent conditions, for both the causal and the concessive conditions. This effect is consistent with the anticipatory looks to target referents during the pre-target region observed in Köhne & Demberg's (2013) visual world study using a similar manipulation. The negativity found on the adjectival region supports the view that participants predicted a very specific lexical item and reacted to the incongruency of that lexical item with the gender-marking of the pre-nominal region.³

² A separate analysis of the adjective region only in the concessive connector condition showed an effect of congruency at the frontal electrodes (*coefficient* = -1.1695, *SE* = 0.5547, *t* = -2.108) and an additional effect at the central ROI (*coefficient* = -1.0153, *SE* = 0.4857, *t* = -2.091), which was not found in the causal connector condition (frontal: *coefficient* = -1.0276, *SE* = 0.5073, *t* = -2.026; central: *t* < 1).

³ A reviewer mentioned that the frontal distribution of the negativity is not typical for the standard (semantic) N400. However, in some studies it was shown that frontal N400s (FN400s) are functionally identical to N400 potentials and reflect

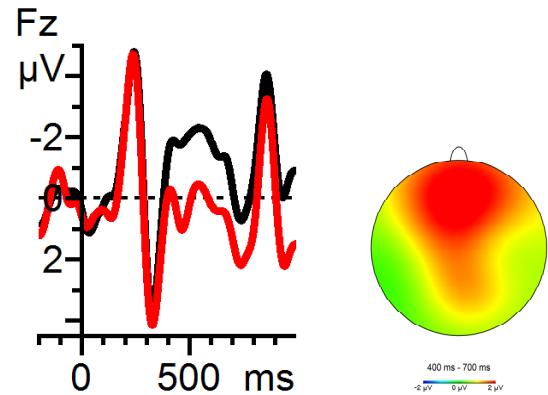


Figure 4: ERP effects on connectors. Black line: causal connector condition; red line: concessive connector condition. The scalp distribution of the effect (concessive minus causal) is plotted on the right side.

Experiment 2: English

Materials

In the English version of this study (see Example 2), the nominal target region contained a noun with vocal vs. consonantal onset. Accordingly, the pre-nominal region contained the determiner 'an' or 'a'. Similar to gender-marking in the German experiment, the pre-nominal determiner was used to test for congruency effects based on people's prediction for the target noun.

2. Mr. Brown was planning to look for new glasses and shoes today. The glasses really are more urgent. **Therefore / However**, he now heads towards **an optician / a shoe shop** that a friend recommended.

Participants

14 students (mean age 26, 8 male) from Saarland University participated in this experiment. All participants were native speakers of English and had normal or corrected-to-normal vision. All participants were paid for their participation.

Procedure

The design, number of items, procedure, and setup were the same as in Experiment 1.

Descriptive results (connector)

The ERP patterns to the connectors are displayed in Figs. 4. ERPs in the concessive condition show a globally distributed positivity compared to the causal condition. The positivity starts at around 400ms and has a time-window between 400ms and 700ms.

semantic processing (e.g. Voss & Federmeier, 2011 but compare Bridge et al. 2012).

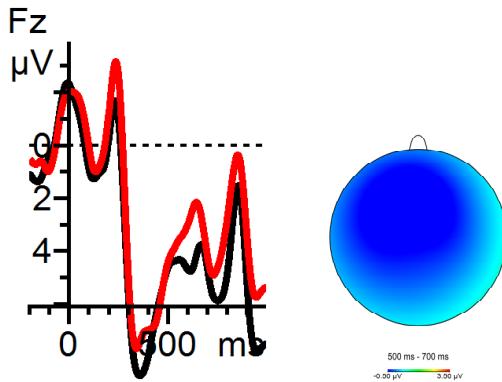


Figure 5: ERP effects on the noun region following the concessive connector. Black line: congruent condition; red line: incongruent condition.

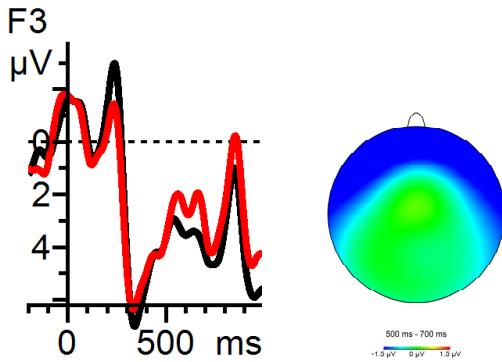


Figure 6: ERP effects on noun region following a causal connector. Black line: congruent condition; red line: incongruent condition.

Statistical analyses (connector)

The statistical analyses were performed in the same way as for the German experiment (400–700ms time-window). The LMM analysis, collapsing over the nine channels (F3, FZ, F4, C3, CZ, C4, P3, PZ, P4), revealed a significant positivity ($coefficient = 1.1327, SE = 0.2565, t = 4.416$) for the concessive connector compared to the causal connector.

A separate analysis of frontal (F3, FZ, F4), central (C3, CZ, C4), and posterior (P3, PZ, P4) electrode ROIs revealed a significant effect for the frontal ($coefficient = 1.6009, SE = 0.4867, t = 3.29$), central ($coefficient = 0.9133, SE = 0.4299, t = 2.125$) and the posterior ROI ($coefficient = 0.8839, SE = 0.3995, t = 2.212$).

Descriptive results (NP)

Visual inspection as well as statistical analyses revealed no significant effect on the determiner but more negative going ERPs for the noun region following the determiner in the incongruent conditions compared to the congruent conditions (Fig. 5 and Fig. 6).

Statistical analyses (NP)

The statistical analyses were performed in the same way as mentioned before for the German adjectival region. The LMM analysis, collapsing over the nine channels (F3, FZ, F4, C3, CZ, C4, P3, PZ, P4), showed a significant effect of congruency ($coefficient = -1.0118, SE = 0.4120, t = -2.456$) but not of connector type ($t < 1$). A separate analysis of frontal, central, and posterior electrode ROIs showed significant effects of congruency at the frontal electrodes ($coefficient = -1.0118, SE = 0.4120, t = -2.456$), central electrodes ($coefficient = -1.1921, SE = 0.4288, t = -2.780$) and posterior electrodes ($coefficient = -1.2292, SE = 0.5440, t = -2.260$). No effects of connector type were found ($t < 1$).⁴

Discussion

The ERP analyses revealed a significant positivity for the concessive connector compared to the causal one, suggesting a model-updating effect, in line with the first experiment on German.

We furthermore found an N400-like effect on the noun region for the incongruent compared to the congruent condition, for both the causal and the concessive conditions, showing that participants incrementally integrated discourse context and connector with upcoming content. We did not find any significant effect on the pre-nominal determiner. While this is consistent with the first experiment, in which we only found the mismatch effect on the adjectival region but not on the determiner, our results in the English experiment remain inconclusive as to whether the incongruity effect reflects active prediction or rather integration of the noun into the preceding context.

General Discussion

In two studies using German and English as test language we investigated the processing of causal versus concessive discourse connectors and the joint influence of context and these connectors on the predictability of a target noun. Our experimental manipulations elicited late positivities on the concessive connector compared to the causal connector in both studies (German and English).

Brouwer et al. (2012) argued that the P600 component is a family of late positivities that reflect several sub-processes involved in the re-organization or updating of the mental representation of what is being communicated (e.g., accommodating new discourse referents, assigning thematic roles, establishing or revising already established relations between entities, etc.). Furthermore, Van Petten & Luka (2012) speculate that while more posteriorly distributed

⁴ Separate analyses for the causal condition and the concessive condition only showed effects at the frontal ($coefficient = -1.7943, SE 0.6582, t = -2.726$), central ($coefficient = -2.2961, SE 0.6103, t = -2.7628$) and posterior ($coefficient = -1.9742, se 0.5846, t = -2.377$) electrodes for the causal connector condition and an effect at the frontal ($coefficient, =-1.6806, SE 0.6182, t = -2.034$) electrodes but no effects for central ($t < 1$) or posterior ($t < 1$) electrodes for the concessive connector condition.

positivities reflect re-processing cost, more frontally pronounced positivities might reflect the cost for disconfirmed predictions or prediction errors. Following this logic, the frontally pronounced positivities at the connectors in our experiments may reflect an updating process triggered by a predicted but disconfirmed causal relation. The N400-like effects at the adjective (German experiment) and the noun (English experiment) suggest that discourse relations are rapidly used to predict (and integrate) upcoming content. In particular, the German data provide strong evidence that the target noun was pre-activated, as the effect was found in the pre-nominal region, a result consistent with previous findings (e.g., DeLong et al., 2005; van Berkum et al., 2005). The English data provide further evidence that discourse relations are processed incrementally and help at least integrating upcoming content.

Conclusions

In two experiments, we found evidence for the hypothesis that an unexpected discourse connector leads to an updating process (late positivity). An N400-like effect on the pre-nominal region in the German experiment furthermore indicates that the processing of discourse connectors elicits predictions of upcoming content. Taken together, these results support a view in which discourse markers help comprehenders to anticipate and integrate upcoming words.

Acknowledgments

Thanks to Andreas Farner for help with the data acquisition.

References

Arbel, Y., Spencer, K. M., & Donchin, E. (2011). The N400 and the P300 are not all that independent. *Psychophysiology*, 48(6), 861–875.

Bates, D., & Sarkar, D. (2007). lme4: Linear mixed-effects models using S4 classes.

Baayen, R. H. (2008). Analyzing linguistic data: A practical introduction to statistics using R. Cambridge: Cambridge University Press.

Berkum, J. J. A. Van, Hagoort, P., & Brown, C. M. (1998). Semantic Integration in Sentences and Discourse: Evidence from the N400, 657–671.

Brehm, E. (2005). Connective ties in discourse: Three ERP-studies on causal, temporal, and concessive connective ties and their influence on language processing. Unpublished doctoral dissertation, Potsdam University, Germany.

Bridger, E. K., Bader, R., Kriukova, O., Unger, K., & Mecklinger, A. (2012). The FN400 is functionally distinct from the N400. *NeuroImage*, 63(3), 1334–1342.

Brouwer, H., Fitz, H., & Hoeks, J. (2012). Getting real about Semantic Illusions: Rethinking the functional role of the P600 in language comprehension. *Brain Research*, 1446, 127–143.

DeLong, K. a, Urbach, T. P., & Kutas, M. (2005). Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. *Nature Neuroscience*, 8(8), 1117–1121.

Drenhaus, H., Zimmermann, M., & Vasishth, S. (2011). Exhaustiveness effects in clefts are not truth-functional. *Journal of Neurolinguistics*, 24(3), 320–337.

Gelman, A., & Hill, J. (2007). *Data analysis using regression and multilevel/hierarchical models*. Cambridge, UK: Cambridge University Press.

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., Paczynski, M., & Ditman, T. (2011). Establishing causal coherence across sentences: an ERP study. *Journal of Cognitive Neuroscience*, 23(5), 1230–1246.

Kutas, M., & Federmeier, K.D. (2011). Thirty years and counting: Finding meaning in the N400 component of the Event-Related Brain Potential (ERP). *Annual Review of Psychology* 62, 621-47.

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

Levy, R., & Jaeger, T. F. (2007). Speakers optimize information density through syntactic reduction. *Advances in neural information processing systems*, 19, 849.

Osterhout, L., & Holcomb, P. J. (1995). Event-Related Potentials and Language Comprehension. In M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of mind* (pp. 171–215). Oxford: Oxford University Press.

Petten, C. Van, & Luka, B. J. (2012). Prediction during language comprehension: Benefits , costs , and ERP components. *International Journal of Psychophysiology*, 83(2), 176–190.

Sharbrough, F., Chartrian, G. E., Lesser, R. P., Lüders, H., Nuwer, M., & Picton, T. W. (1995). American Electroencephalographic Society guidelines for standard electrode position nomenclature. *Journal of Clinical Neurophysiology*, 8, 200–202.

Van Berkum, J. J. a., Brown, C. M., Zwitserlood, P., Kooijman, V., & Hagoort, P. (2005). Anticipating Upcoming Words in Discourse: Evidence From ERPs and Reading Times. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 31(3), 443–467.

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

Voss, J. L., & Federmeier, K. D. (2012). FN400 potentials are functionally identical to N400 potentials and reflect semantic processing during recognition testing. *Psychophysiology*, 48(4), 532–546.