Neural correlates of conceptualisation difficulties during the preparation of complex utterances.

Citation for published version (APA):

Marek, A., Habets, B., Jansma, B. M., Nager, W., & Muent, T. F. (2007). Neural correlates of conceptualisation difficulties during the preparation of complex utterances. *Aphasiology*, 21(12), 1147-1156. <https://doi.org/10.1080/02687030600646577>

Document status and date:

Published: 01/01/2007

DOI:

[10.1080/02687030600646577](https://doi.org/10.1080/02687030600646577)

Document Version:

Publisher's PDF, also known as Version of record

Document license:

Taverne

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.umlib.nl/taverne-license

Take down policy

If you believe that this document breaches copyright please contact us at:

repository@maastrichtuniversity.nl

providing details and we will investigate your claim.

Download date: 26 Apr. 2023

Neural correlates of conceptualisation difficulty during the preparation of complex utterances

Annette Marek , Boukje Habets , Bernadette M. Jansma , Wido Nager & Thomas F. Münte

To cite this article: Annette Marek , Boukje Habets , Bernadette M. Jansma , Wido Nager & Thomas F. Münte (2007) Neural correlates of conceptualisation difficulty during the preparation of complex utterances , Aphasiology, 21:12, 1147-1156, DOI: [10.1080/02687030600646577](https://doi.org/10.1080/02687030600646577)

To link to this article: <https://doi.org/10.1080/02687030600646577>

Published online: 26 Nov 2007.

[Submit your article to this journal](#)

Article views: 79

[View related articles](#)

Citing articles: 1 [View citing articles](#)

Neural correlates of conceptualisation difficulty during the preparation of complex utterances

Annette Marek and Boukje Habets

Otto von Guericke University, Magdeburg, Germany

Bernadette M. Jansma

Maastricht University, The Netherlands

Wido Nager

Medical School Hannover, Germany

Thomas F. Münte

Otto von Guericke University, Magdeburg, Germany

Background: In language production, conceptualisation of the utterance precedes lemma retrieval, phonological encoding, and articulation. Knowledge about the neural correlates of conceptualisation is scarce.

Aims: The study aimed at the delineation of neurophysiological correlates of the macro-planning aspect of conceptualisation by manipulating difficulty of conceptualisation.

Methods & Procedures: Utterances were elicited by visual arrays containing a network of eight different shapes (e.g., circle, square) of different colours. Upon the appearance of an arrow in the display, participants had to describe either the direction of the arrow only (simple condition), the direction and the destination shape (medium condition), or the direction, the destination shape, and its colour (complex condition). Event-related brain potentials (ERPs) were recorded from young healthy native speakers of German and analysed for epochs starting 100 ms prior to the onset of the arrow stimulus until 600 ms thereafter, i.e., prior to the onset of the vocalisation. ERPs were quantified by mean amplitude measures.

Outcomes & Results: ERPs uncontaminated by vocalisation artefacts were obtained. Brain potentials in the medium and complex conditions were more positive going than those from the simple condition from 300 ms onwards. This effect had a centro-parietal distribution akin the P300 component.

Conclusions: Reliable electrophysiological effects of conceptualisation difficulty were obtained, opening new possibilities for the neurophysiological investigation of language production in healthy participants and those with non-aphasic language disorders. The distribution of the conceptualisation effect suggests that it reflects general effects of conceptualisation difficulty (e.g., demand for processing resources) rather than specific steps of the language planning process.

Address correspondence to: Thomas F. Münte MD, Dept. of Neuropsychology, Otto-von-Guericke Universität, Universitätsplatz 2, Gebäude 24, 39106 Magdeburg, Germany.
E-mail: thomas.muente@medizin.uni-magdeburg.de

Supported by DFG grant MU1311/13-1 to TFM and NWO ASPASIA grant nr 015.001.053 to B. M. Jansma (Schmitt). We thank A. Niesel and J. Kilian for technical support.

Current psycholinguistic models suggest that we know what we want to say, i.e., we have a *concept* of our next utterance, before we decide how we are going to say it. The language production model of Levelt (Levelt, 1989; Levelt, Roelofs, & Meyer, 1999), for example, comprises three major stages: conceptualisation, formalisation, and articulation. The differentiation of these levels is based on empirical data on speech errors and picture naming latencies (Levelt et al., 1999). While Levelt's theory explicates the successive computational stages of language production and the representations involved in these computations, the experimental work reported in the present paper does not hinge on this particular model, since differences between Levelt's model and other models of word production (e.g., Berg & Schade, 1992; Garrett, 1982; Harley, 1984; Motley, Baars, & Camden, 1983; Stemberger, 1985) do not concern the assumed processing levels but the exact nature of the information flow between them.

In addition to the question of *what* stages can be distinguished during language production, it has also been asked *when* the respective types of information become available—see Pechmann and Zerbst (2002) for picture naming studies, and Indefrey and Levelt (2004) and Jansma, Rodriguez-Fornells, Möller, and Münte (2004) for electrophysiological studies.

This paper is a first attempt at a neurophysiological characterisation of the conceptualisation stage. According to Levelt (1989, Ch. 4) the conceptualisation stage can be divided into two successive steps: macro-planning and micro-planning. During macro-planning the speaker has to decide—depending on the particular environment—which intentions or ideas are to be transferred into speech. Take, for example, the events during a livestock auction. The speaker might conceptualise a cow and a horse. To unambiguously identify certain objects, however, it might be necessary to provide additional details (the black cow; the small white horse), for instance if there are more than two cows or horses. Following the selection of the particular concepts, these must be lexicalised, i.e., translated into speech (Deutsch & Pechmann, 1982).

After this selection the speaker has to decide in which order an event will be uttered. One principle that has been identified is that of “natural order”. According to this principle, the sentence “After he bought the cow, the horse collapsed” is more natural in terms of chronological order than the sentence “Before the horse collapsed, he bought the cow”.

In a second step during conceptualisation, the speaker has to carry out the specific “micro-planning” of the utterance. For this micro-planning it is important whether or not a particular concept belongs to the common ground of knowledge. If a concept is not yet available to the listener it needs to be introduced (I have seen *a* cow). If the listener is already familiar with the concept, a definite article might be chosen (I have bought *the* cow). Now, if the speaker wants to focus on a concept that is already in the *common ground of knowledge*, he or she might do that by bringing the concept to the front of the utterance “*The* cow is standing on the hill”. Finally, if the concept is already in focus, it can be referred to by a pronoun “*It* is looking at the stable”.

In the current experiment, we focused on the macro-planning aspect and systematically manipulated conceptualisation complexity. In particular, we instructed participants to produce short utterances, describing the path of an arrow in a network of geometrical symbols (see Figure 1 for a description). Depending on the instructions, participants were required to mention the direction of the arrow

Figure 1. Example for a stimulus in the “network”-paradigm. As the grey-scale figure does not allow the different colours to be distinguished, the symbols’ colours are indicated for illustrative purposes only.

only (easy conceptualisation=direction only), the direction of the arrow and the target symbol (medium=direction plus noun), or the direction of the arrow, the target symbol and its colour (complex=direction plus colour plus noun). To delineate the neural correlates of the conceptualisation process, event-related brain potentials (ERPs) were recorded time-locked to the onset of the arrow.

Previous studies with ERPs have addressed the sequence of information access during language production. In two studies employing a brain potential linked to response preparation called the lateralised readiness potential (LRP), Van Turenout and colleagues found that semantic information is encoded about 120 ms before phonological information, and that syntactic properties are encoded about 40 ms before phonological information (Turenout, Hagoort, & Brown, 1998; van Turenout, Hagoort, & Brown, 1999; van Turenout, Hagoort, & Brown, 1997). These findings were further elaborated by a series of studies from our group employing the N200 component, which showed that semantic information is accessed before syntactic and phonological information during language production (Rodriguez-Fornells, Schmitt, Kutas, & Münte, 2002; Schmitt, Münte, & Kutas, 2000; Schmitt, Rodriguez-Fornells, Kutas, & Münte, 2001; Schmitt, Schiltz, Zaake, Kutas, & Münte, 2001). While delivering precise timing information, the particular technique used by van Turenout et al. and our group in these previous studies is of restricted value for the investigation of conceptualisation, as the paradigm relies on dual choices in categorisation—and explicit categorisation may influence implicit conceptualisation. To the best of our knowledge the present study represents a first attempt to capture these processes electrophysiologically.

No prior ERP studies have addressed conceptualisation in speech production. In the domain of functional neuroimaging, a PET study assessing the production of discourse in English and American Sign Language reported widespread activations including extrastriate visual cortex, precuneus, and posterior cingulate cortex but also prefrontal regions that were thought to be related to conceptual processing (Braun, Guillemin, Hosey, & Varga, 2001). Unfortunately, however, the task requirements did not allow specific targeting of brain regions that might support the macro-planning stage under investigation in the current study. Thus, we could not formulate explicit hypotheses regarding the ERP effects that would be expected in the current study.

METHOD

Participants

A total of 13 right-handed, neurologically intact, native speakers of German (eight women, mean age 23, range 22–29) were paid to participate in the experiment after giving written informed consent.

Stimuli and procedure

An adapted version of the network paradigm was used (Levelt, 1983; Levelt et al., 1999; Oomen & Postma, 2001). A total of 24 different “network” stimuli were used as illustrated in Figure 1. These were presented on a 21-inch video monitor located in front of the participants and subtended 8/6 degrees in width/height at the viewing distance of 200 cm. The position of the geometric figures and their colour was different for each of the network stimuli.

Each trial (comprising the successive presentation of five arrow stimuli and thus the elicitation of five utterances) began with the presentation of one of three different instructions (easy: *Describe direction!*; medium: *Describe direction and symbol!*; hard: *Describe direction, symbol and colour!*),¹ which stayed on the screen for 1500 ms and was replaced by the network stimulus containing an arrow (see Figure 1). The starting point of the first arrow was always the mid-point.

The task of the participant was to produce an utterance according to the instruction upon the appearance of the arrow. After 6500 ms the arrow was replaced by another one, which had the end-point of the first as its starting point. Again, the participant had to describe the event according to the instruction. This procedure was repeated three more times such that five utterances were obtained per network stimulus.

The following prototypical utterances were expected by the participants. Easy condition (direction only): “*nach unten, nach oben, nach rechts nach links, zur Mitte*” (*downwards, upwards, to the right, to the left, towards the middle*). Medium condition (direction and symbol): “*nach unten zum Dreieck*” (*downwards to the triangle*). Complex condition (direction, symbol, colour): “*nach unten zum grauen Dreieck*” (*downwards to the grey triangle*). In each of the easy, medium, and complex conditions, 120 utterances were obtained. The order of conditions was randomised and changed from trial to trial. In total, 360 stimuli were presented ([24 networks] × [5 arrows] × [3 conditions]), distributed over four blocks. The total duration of the experiment was 45 minutes including breaks.

Electrophysiological recording

The ERPs were recorded from the scalp using tin electrodes mounted in an elastic cap and located at 29 standard positions (Fp1/2, F7/8, F5/6, F3/4, C3/4, C5/6, T7/8, Fz, Cz, Pz, Cp3/4, Cp5/6, Tp7/8, P3/4, P7/8, O1/2). Biosignals were re-referenced off-line to the mean of the activity at the two mastoid processes. Vertical eye movements were monitored with an electrode at the infraorbital ridge of the right eye vertical EOG. Electrode impedances were kept below 5 kOhm.

¹ The instructions in German were (in the same order): *Beschreiben Sie die Richtung!*; *Beschreiben Sie Richtung und Form!*; *Beschreiben Sie Richtung, Form und Farbe!*

The electrophysiological signals were filtered with a bandpass of 0.01–70 Hz (half-amplitude cutoffs) and digitised at a rate of 250 Hz. Eye-blink artefacts were detected using individualised amplitude criteria on the vertical EOG and frontopolar EEG channels. These were determined by measuring the amplitudes of typical blinks in an individual participant and adjusting the threshold such that contaminated trials were reliably rejected.

Artefact-free and correct trials were averaged separately for each condition but across all five utterances per trial. Epochs started 100 ms before the onset of each arrow and were truncated at 600 ms to avoid contamination by speech artefacts.

ERP averages were quantified by a mean amplitude measure (time window 350 to 500 ms), which was subjected to a repeated measures analysis of variance. The time window was selected based on visual inspection of the grand average waves. For all statistical effects involving two or more degrees of freedom in the numerator, the Greenhouse-Geisser epsilon was used to correct possible violations of the sphericity assumption (Jennings & Wood, 1976). Exact *p*-value after correction will be reported. Tests involving electrode $\times$ condition interactions (e.g., factors such as hemisphere or anterior–posterior electrode location) were carried out on data corrected using the vector normalisation procedure described by McCarthy and Wood (1985).

RESULTS

Overt behaviour

Utterances were recorded with a tape recorder and speech errors and interjections (e.g., “ah”) were scored off-line by the experimenter. As Figure 2 illustrates, these occurred more often in medium and complex conditions, $F(2, 24) = 9.66$, $p < .001$. Voice onset latencies were not determined.

ERP data

The grand average ERPs time-locked to the onset of the arrow and collapsed over all five utterances of a trial are shown in Figure 3. All conditions are characterised by an initial negativity with a peak latency of about 130 ms followed by a positive peak at 210 ms. From about 300 ms onwards a differentiation between the different

Figure 2. Rates of errors and interjections for the three different conditions.

Figure 3. Grand average ERPs ($n=13$) for several midline and lateral temporal electrodes. Both medium and complex conditions were associated with a more positive-going ERP starting around 300 ms after the onset of the arrow. On the right spline-interpolated isovoltage maps show the distribution of the difference-potential (complex minus simple; medium minus simple) at 500 ms post-onset of the arrow. A centro-parietal maximum is revealed.

conditions is observed. The medium and complex conditions are associated with a more positive ERP waveform. The distribution of this effect is illustrated by spline-interpolated voltage maps computed from the difference waves obtained by subtracting the waveforms of the medium (or complex) condition from those of the simple condition. For both, the medium and complex difference waves, a parietal distribution of the positivity was seen.

This effect was confirmed using a mean amplitude measure in the time window 350 to 500 ms (midline electrodes Fz, Cz, Pz), which revealed a main effect of condition, $F(2, 24) = 8.63$, $p = .0015$. Post-hoc comparisons showed, further, that the medium and the complex condition both differed from the simple condition ($p < .004$ and $p < .006$, respectively), while they did not differ from each other.

Figure 4 shows the ERPs separately for the five different utterances of a trial. While marked differences were seen between the first and the subsequent utterances in each condition, the overall finding of a more positive waveform for medium and complex conditions was found for all utterances. This was corroborated by an ANOVA introducing utterance (1 to 5) as a separate factor in addition to condition and electrode site, which revealed a main effect of utterance, $F(4, 48) = 13.71$, $p < .0001$, but no condition by utterance interaction, $F(8, 96) = 2.18$, *ns*.

DISCUSSION

The present experiment required participants to describe standardised visual events using utterances of three different levels of conceptual complexity. In the preparation of these utterances, i.e., prior to their articulation, a robust ERP effect was found

Figure 4. Grand average ERPs for the Cz electrode site. While the first utterance of a trial was associated with a more negative ERP than the subsequent stimulus in all three conditions, the overall effect—i.e., a more positive ERP for the medium and complex waveform for the medium and complex conditions—is seen for all five utterances.

that differed across conditions. The medium-level and complex utterances were associated with a widespread positivity compared to the easy condition. It is noteworthy that our experimental set-up, while requiring the participants to utter their responses overtly, also allowed us to record brain potentials uncontaminated by vocalisation artefacts, as we focused on the period immediately following the arrow (i.e., focusing on the planning phase prior to the vocalisation). Overt vocalisation has been used in a small number of previous ERP studies (Eulitz, Hauk, & Cohen, 2000; Liotti, Woldorff, Perez, & Mayberg, 2000), each showing that reliable and artefact-free ERPs can be generated in the interval between a stimulus and the respective vocalisation. Importantly, both Liotti et al. (2000) and Eulitz et al. (2000) used discrete stimuli and discrete vocalisations. This situation is similar to the current experiment. Other researchers have rather used delayed vocalisation procedures (Jescheniak, Schriefers, Garrett, & Friederici, 2002) or have used button-press responses based on the covertly produced utterance (Turennout et al., 1998; Schmitt et al., 2000) in order to avoid vocalisation artefacts, but the current experiment suggests that this might not be necessary.

The nature of the “conceptualisation” effect

The present study aimed at a manipulation of conceptualisation difficulty. That this manipulation has been successful is corroborated by the increased error rate in the medium and complex condition. The question therefore arises whether the observed ERP difference is a neural correlate of conceptualisation processes per se or whether it rather reflects more general effects, such as a greater demand for processing resources, of task difficulty.

Both timing and distribution (centro-parietal maximum) of the current “conceptualisation” effect suggest that it is an instance of the so-called P300 component. This component is one of the most widely researched ERP effects and can be seen in many different circumstances. While the P300 was first described as being evoked by infrequent deviant stimuli and is triggered most effectively when these deviant events are attended and task-relevant (Donchin, 1981; Verleger, 1988), further research (summarised, for example, by Münte, Urbach, Düzel, & Kutas, 2000), has shown that it is not necessary for a stimulus to be a rare deviant to elicit a P300. Rather, the P300 occurs in response to task-relevant stimuli and its amplitude reflects the difficulty of the task associated with the stimulus as well as its task relevance (Johnson, 1986; Kutas, McCarthy, & Donchin, 1977). Given its similarity

to the P300 component, it does not seem appropriate to interpret the difference between medium/complex conditions and the simple conditions as a direct correlate of conceptualisation processes.

Please note, however, that another ERP effect, the so-called P600/SPS (SPS=syntactic positive shift), obtained in response to syntactic violations or to words that indicate the necessity for reanalysis of a sentence, has triggered a discussion along similar lines. While originally thought to specifically index syntactic processing (hence its name) (Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992), others (Coulson, King, & Kutas, 1998) have pointed out the similarity of the effect to the generic P300 component or have demonstrated that the P600/SPS is not specific to syntactic processes (Kolk, Chwilla, van Herten, & Oor, 2003; Kuperberg, Sitnikova, Caplan, & Holcomb, 2003; Münte, Heinze, Matzke, Wieringa, & Johannes, 1998; van Herten, Kolk, & Chwilla, 2005). In spite of this apparent non-specificity of the P600/SPS it has been used fruitfully to investigate syntactic processing, as numerous research papers and recent theoretical work (summarised, e.g., by Hagoort, 2003, and Friederici, 2002) demonstrate. It remains to be shown by future experiments whether or not the amplitude variations of the positive component observed in the present study can be used to describe and investigate conceptualisation processes during language production in a similar fashion.

Alternatively, taking for granted that the P600/SPS reflects syntactic processing and assuming that it could be similar for speech comprehension and production, the current data might speak to syntactic processing in production. The observed increase in positivity from simple to medium and complex conditions might reflect the increased demand of syntactic encoding that goes along with the increase in conceptualisation complexity. Interestingly, the current paradigm features three levels of conceptualisation (simple, medium, complex) but only two levels of syntactic complexity. In the simple condition, there is hardly any syntactic processing required (required utterances: *nach oben*, *nach rechts* etc. corresponding to *upwards*, *to the right*), while in the medium and complex conditions syntactic processing of case marking on the adverbs (*zum/zur*), depending on the syntactic gender of the noun (*der Kreis/die Raute* → *the_{masc} circle/the_{fem} rhombus*) was required. The involvement of the colour adjective in the complex condition might not add to the syntactic complexity as its inflection is independent of the dative case and of the noun's gender (*zur grünen Raute*, *zum grünen Kreis* → *to the_{fem} green rhombus*, *to the_{masc} green circle*). Thus, the fact that no difference in ERP between medium and complex conditions was observed could indicate that the ERP is sensitive to the syntactic complexity differences rather than the conceptualisation difficulty per se (see Heim, Opitz, & Friederici, 2002; Indefrey et al., 2001; Indefrey, Hellwig, Herzog, Seitz, & Hagoort, 2004 for neuroimaging findings on correlates of syntactic complexity during production).

Further experimentation is needed to pinpoint more precisely the cognitive process indexed by the conceptualisation effect found in the present experiment. While neutral with regard to the specific architecture of the language production system, it may serve as a marker for the timing of conceptualisation processes.

REFERENCES

- Berg, T., & Schade, U. (1992). The role of inhibition in a spreading-activation model of language production: I. The psycholinguistic perspective. *Journal of Psycholinguistic Research*, 21, 405–434.
- Braun, A. R., Guillemin, A., Hosey, L., & Varga, M. (2001). The neural organization of discourse: An H2 15O-PET study of narrative production in English and American sign language. *Brain*, 124, 2028–2044.
- Coulson, S., King, J. W., & Kutas, M. (1998). Expect the unexpected: Event-related brain response to morphosyntactic violations. *Language and Cognitive Processes*, 13, 21–58.
- Deutsch, W., & Pechmann, T. (1982). Social interaction and the development of definite descriptions. *Cognition*, 11, 159–184.
- Donchin, E. (1981). Presidential address, 1980. Surprise! ... Surprise? *Psychophysiology*, 18, 493–513.
- Eulitz, C., Hauk, O., & Cohen, R. (2000). Electroencephalographic activity over temporal brain areas during phonological encoding in picture naming. *Clinical Neurophysiology*, 111, 2088–2097.
- Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *Trends in cognitive science*, 6, 78–84.
- Garrett, M. F. (1982). Production of speech: Observations from normal and pathological language use. In A. W. Ellis (Ed.), *Normality and pathology in cognitive functions* (pp. 19–76). London: Academic Press.
- Hagoort, P. (2003). How the brain solves the binding problem for language: A neurocomputational model of syntactic processing. *Neuroimage*, 20(Suppl 1), S18–S29.
- Hagoort, P., Brown, C. M., & Groothusen, J. (1993). The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes*, 8, 439–483.
- Harley, T. A. (1984). A critique of top-down independent levels models of speech production: Evidence from non-plan-internal speech errors. *Cognitive Science*, 8, 191–219.
- Heim, S., Opitz, B., & Friederici, A. D. (2002). Broca's area in the human brain is involved in the selection of grammatical gender for language production: Evidence from event-related functional magnetic resonance imaging. *Neuroscience Letters*, 328, 101–104.
- Indefrey, P., Brown, C. M., Hellwig, F., Amunts, K., Herzog, H., & Seitz, R. J., et al. (2001). A neural correlate of syntactic encoding during speech production. *Proceedings of the National Academy of Science USA*, 98, 5933–5936.
- Indefrey, P., Hellwig, F., Herzog, H., Seitz, R. J., & Hagoort, P. (2004). Neural responses to the production and comprehension of syntax in identical utterances. *Brain and Language*, 89, 312–319.
- Indefrey, P., & Levelt, W. J. (2004). The spatial and temporal signatures of word production components. *Cognition*, 92, 101–144.
- Jansma, B. M., Rodriguez-Fornells, A., Möller, J., & Münte, T. F. (2004). Electrophysiological studies of speech production. In T. Pechmann & C. Habel (Eds.), *Multidisciplinary approaches to language production* (pp. 230–261). Berlin: Mouton de Gruyter.
- Jennings, J. R., & Wood, C. C. (1976). The epsilon-adjustment procedure for repeated-measures analyses of variance. *Psychophysiology*, 13, 277–278.
- Jescheniak, J. D., Schriefers, H., Garrett, M. F., & Friederici, A. D. (2002). Exploring the activation of semantic and phonological codes during speech planning with event-related brain potentials. *Journal of Cognitive Neuroscience*, 14, 951–964.
- Johnson, R. Jr. (1986). A triarchic model of P300 amplitude. *Psychophysiology*, 23, 367–384.
- Kolk, H. H., Chwilla, D. J., van Herten, M., & Oor, P. J. (2003). Structure and limited capacity in verbal working memory: A study with event-related potentials. *Brain and Language*, 85, 1–36.
- Kuperberg, G. R., Sitnikova, T., Caplan, D., & Holcomb, P. J. (2003). Electrophysiological distinctions in processing conceptual relationships within simple sentences. *Cognitive Brain Research*, 17, 117–129.
- Kutas, M., McCarthy, G., & Donchin, E. (1977). Augmenting mental chronometry: The P300 as a measure of stimulus evaluation time. *Science*, 197, 792–795.
- Levelt, W. J. (1983). Monitoring and self-repair in speech. *Cognition*, 14, 41–104.
- Levelt, W. J. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.
- Levelt, W. J., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioural Brain Science*, 22, 1–38.
- Liotti, M., Woldorff, M. G., Perez, R., & Mayberg, H. S. (2000). An ERP study of the temporal course of the Stroop colour-word interference effect. *Neuropsychologia*, 38, 701–711.
- 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.

- Motley, M. T., Baars, B. J., & Camden, C. T. (1983). Experimental verbal slip studies: A review and an editing model of language encoding. *Communication Monographs*, 50, 79–101.
- 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, 217–226.
- Münte, T. F., Urbach, T. P., Düzel, E., & Kutas, M. (2000). Event-related brain potentials in the study of human cognition and neuropsychology. In F. Boller, J. Grafman, & G. Rizzolatti (Eds.), *Handbook of Neuropsychology*, 2nd edition, Vol. 1 (pp. 139–235). New York: Elsevier.
- Oomen, C. C., & Postma, A. (2001). Effects of time pressure on mechanisms of speech production and self-monitoring. *Journal of Psycholinguistic Research*, 30, 163–184.
- Osterhout, L., & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language*, 31, 785–806.
- Pechmann, T., & Zerbst, D. (2002). The activation of word class information during speech production. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 28, 233–243.
- Rodriguez-Fornells, A., Schmitt, B. M., Kutas, M., & Münte, T. F. (2002). Electrophysiological estimates of the time course of semantic and phonological encoding during listening and naming. *Neuropsychologia*, 40, 778–787.
- Schmitt, B. M., Münte, T. F., & Kutas, M. (2000). Electrophysiological estimates of the time course of semantic and phonological encoding during implicit picture naming. *Psychophysiology*, 37, 473–484.
- Schmitt, B. M., Rodriguez-Fornells, A., Kutas, M., & Münte, T. F. (2001). Electrophysiological estimates of semantic and syntactic information access during tacit picture naming and listening to words. *Neuroscience Research*, 41, 293–298.
- Schmitt, B. M., Schiltz, K., Zaake, W., Kutas, M., & Münte, T. F. (2001). An electrophysiological analysis of the time course of conceptual and syntactic encoding during tacit picture naming. *Journal of Cognitive Neuroscience*, 13, 510–522.
- Stemberger, J. P. (1985). An interactive activation model of language production. In A. W. Ellis (Ed.), *Progress in psychology of language* (pp. 143–186). London: Lawrence Erlbaum Associates Ltd.
- Turenout, M., Hagoort, P., & Brown, C. M. (1998). Brain activity during speaking: From syntax to phonology in 40 milliseconds. *Science*, 280, 572–574.
- van Herten, M., Kolk, H. H., & Chwilla, D. J. (2005). An ERP study of P600 effects elicited by semantic anomalies. *Cognitive Brain Research*, 22, 241–255.
- van Turenout, M., Hagoort, P., & Brown, C. (1999). The time course of grammatical and phonological processing during speaking: Evidence from event-related brain potentials. *Journal of Psycholinguistic Research*, 28, 649–676.
- van Turenout, M., Hagoort, P., & Brown, C. M. (1997). Electrophysiological evidence on the time course of semantic and phonological processes in speech production. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 23, 787–806.
- Verleger, R. (1988). A critique of the context updating hypothesis and an alternative interpretation of P3. *Behavioural and Brain Science*, 11, 343–427.