Electrophysiological research on conversation and discourse processing

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To appear in: Holtgraves, T. (Ed.), *Oxford Handbook of Language and Social Psychology*, Oxford University Press

Book Title: The Oxford Handbook of Language and Social Psychology
Chapter Title: Electrophysiological research on conversation and discourse processing

Abstract: Research into the electrophysiology of language comprehension has essentially been 'speakerless'. This has left three vital aspects of communication -- it is social, pragmatic, and dynamic -- severely under-researched. The current chapter makes a case for the investigation of language users involved in active conversation, and describes the problems and possibilities that accompany this choice of subject. It gives an overview of what is currently known about how the social, pragmatic and dynamic puzzles of communication are solved by the brain, and describes the well-filled toolbox of language related ERP (Event Related brain Potentials) components (e.g., Nref, N400, P600) that are to our disposal.

Keywords: Language, Communication, Conversation, ERPs (Event-Related brain Potentials), Pragmatics, N400, P600, Nref.

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1. Introduction

Research into the electrophysiology of language comprehension has essentially been 'speakerless'. For over thirty years, participants in language experiments have read isolated and unconnected sentences, word-by-word, from a computer screen. In the last decade or so, there has been increased, though certainly not overwhelming interest in presenting language stimuli auditorily, together with a subtle shift from studying isolated sentences toward looking at multi-sentence discourse or even mini-dialogues. However, in all of these studies, participants are, at best, detached observers of short, unrelated fragments of conversations, between people they don't know and don't care about. A number of recent studies (e.g., Dumas, Nadel et al., 2010; Dumas, Chavez, et al., 2012; Stephens, Silbert, & Hasson, 2010; Suda et al., 2010; for an overview see Babiloni & Astolfi, 2012) took issue with that, and started to investigate participants actively taking part in an interaction. Unfortunately, these studies had to restrict themselves to looking at very global measures of contiguity and synchronicity of processing; none of them takes into account *what* participants say to each other, *when* they say it, and *how* they say it.

This state of affairs is not as strange as it seems. For investigating brain activity through the analysis of ERPs (Event-Related brain Potentials), the experimenter needs full control over the experimental stimuli: what they are, how they are realized, and *exactly* when they appear. As yet, there is no way to get this kind of control over utterances in free-running interactions (Schilbach et al., 2012; see also Van Berkum, 2012). However, as we will argue later, there are ways to approximate real conversation, while remaining in strict experimental control over content, form and timing (e.g., the Dialogue Immersion Paradigm: Hoeks, Schoot, Neijmeijer, & Brouwer, in prep.). But besides this rather technical reason, there is also a more historical reason for the relative neglect of conversation as a research topic. Psycholinguistic investigations of language processing started out with the implicit adage that if you want to know more about language processing, you should start with its basic building blocks: words. Hence, psycholinguistics set off with the investigation of written words, often presented in isolation. It was soon recognized, however, that word recognition and meaning activation crucially depend on the *sentential context* in which the words occur, and eventually also that the processing of a sentence can only be properly understood if the larger *context* of the sentence is taken into account. What we are seeing now, is the beginning of a third paradigmatic shift in language processing research: from investigating reader's cognitive responses to a sentence or a text, to having participants actively interact in conversation.

1.1. Why active conversation?

Once a participant enters into an actual conversation, three vital aspects of communication come to the fore that are severely under-researched: 1) communication is *social* -- for instance, speakers and hearers use a variety of communication strategies in order not to damage the public image, or 'face' each puts forward -- 2) communication is *pragmatic* -- communication is ultimately a means towards a goal, and precisely the appreciation of this goal-directedness makes our interlocutors try and make sense of what we say (or do). This 'sense making' can sometimes be quite fast, but often requires considerable inferencing, as the words and sounds uttered by our conversational partners (or other, nonverbal, signals that they emit) are at best *pieces of evidence* (cf., Sperber & Wilson, 1986, 1995) or *instructions* to make us think, do, and feel things. Understanding an utterance, we assume, always requires inferencing, or pragmatic processing, on the basis of the communication at hand, and of what is known about the conversational context, including the speaker, and 3) communication is *dynamic*; it is a process that must be monitored and managed (Clark & Brennan, 1991). Turns must be negotiated and signaled, and feedback is necessary to indicate that the listener understood what the speaker meant to communicate. This 'backchannel information' can consist of head nodding, smiling, making small sounds such as “uhuh” or “hmhm”, but can also be fully linguistically expressed and take the form of occasionally completing an utterance of the speaker (with one or few words), or even with brief, but complete turns ("yes", "that's odd!", "incredible!", "Is that so?"). Leaving out such backchannel information may lead socially sensitive speakers to stop talking altogether (Kraut, Lewis, & Swezey, 1982).

It is important to note that these social, pragmatic, and dynamic dimensions are highly interrelated. For instance, frequency and timing of turn-taking in a conversation is regulated by social factors such as power distance and familiarity between the interlocutors. Also, diverging from socially appropriate turn-taking and backchannel scripts will lead to an increase in pragmatic processing aimed at ascertaining the possible meaning of these transgressions. Furthermore, the 'indirectness' of an utterance, which is strongly determined by social rules of engagement (here, a specific set of rules is applicable, which we may refer to as 'linguistic politeness'), will affect the pragmatic processing necessary to uncover the intended meaning of an utterance. Despite the commonalities between the three dimensions, it is fruitful to distinguish them and study them separately.

It could be argued that there is no real need to study active conversation, with all its intricacies, as essentially every important process and representation will also be present when conversations are *overheard*. And indeed, we all are very familiar with the role of 'eavesdropper', if not in real situations, then surely when reading a novel, or watching a play or a movie. On each of these occasions, we observe other people interact, and converse, and we can readily predict the feelings and mental representations of the protagonists. However, it is also intuitively clear that being an observer is something quite different from being a real actor. This is of course especially true for language production, but it is likely to be equally applicable to language comprehension. For one thing, you understand a conversation better if you are a real interactant than if you are merely overhearing (Schober & Clark, 1989). Another important concept is 'involvement'. When we watch movies, we are motivated to understand what the characters in a play mean by their utterances and behavior. We can also be emotionally involved, at least to some degree. However, if you are a real actor (instead of an observer), it becomes essential that you understand what the other person is saying, because your *face* is at stake, which is clearly not the case when you for instance watch a conversation on television. Lots of things may go wrong during an actual conversation; you might not be able to find a good answer to a question, you stutter, your conversational partner is not very considerate, leading you to experience face loss, which, though often partial and temporary, can lead to several kinds of negatively valenced emotions (especially embarassment, but also fear, guilt, sadness, ...). In addition, as an actor, you may not reach your personal goals if you do not understand what the other person is saying and cannot act upon that appropriately. Hence, you will be trying your best to make sense of what the other person wants to communicate. Thus, it seems likely that the processes and representations involved in language use are different in degree and possibly also in type when we actively interact versus when we observe the interactions of others.

For the reasons given above, we would like to propose that the main object of study for the electrophysiology of language use should be *active conversation*. We believe it is not enough to look at participants as observers of interaction -- although that is certainly a considerable improvement over the word-by-word Rapid Serial Visual Presentation (RSVP) method that is still current -- as active conversation may involve different processes and different representations. This conclusion is shared by Schilbach et al. (2012), who add: "*The state of the art in neuroimaging provides severe limitations to studying free-running interactions using the full range of verbal and nonverbal channels. Most likely successful studies will need to identify and isolate salient communicative subsystems.*" (Schilbach et al., 2012, p. 33). Moving towards free-running interaction presents a formidable challenge to experimenters, and looking at specific methodological setups focusing on subsystems seems to be a necessary step. One approach to bring conversations under experimental control is through *scripting*. Hoeks et al. (in prep.) use what they call the *Dialogue Immersion Paradigm* or DIP to have participants take part in a conversation. What participants do not know is that the responses they get from their conversational partner are prerecorded, which permits reliable presentation of language stimuli with millisecond precision. Participant's own contributions are scripted so as to match with these responses. Though this can hardly be seen as free-running interaction, it does permit the crucial involvement of the participant in what she thinks is a real exchange, where the participant becomes sensitive to face-related issues, to pragmatics, and to the dynamics of backchannel information and turn-taking—the participant is *immersed* into the conversation. It is not impossible that advances in ERP-recording techniques and innovations in experimental design will lead to interactions that are more free than the very restrictive DIP. However, for now, it seems to be a viable paradigm to study aspects of active conversation.

1.2. Why Event-Related Potentials?

The DIP described in the previous section was put forward as a solution to technical and methodological problems that arise when a researcher wants to use ERPs to investigate the neural correlates of language processing. But why would we want to use ERPs in the first place? In a recent overview, Van Berkum (2012) deplores the state of affairs in the electrophysiology of language, and paints a gloomy picture of a field with lots of scattered findings, and little consensus on what they mean. However, since the time he wrote his chapter, there have been new developments. Brouwer, Fitz, & Hoeks (2012), for instance, offer a parsimonious account of the two most prominent ERP components, the so-called "N400" and "P600", which we will discuss in more detail below. Furthermore, Brouwer & Hoeks (2013) have combined this account of language related ERP components into a core anatomical model of language processing. But let us start by describing ERPs and explain how they can inform theories of language processing.

2. The Electrophysiology of Language Processing

2.1. What are Event-Related Potentials?

The human brain contains billions of interconnected neurons (or *nerve cells*), which are effectively tiny information processors. Through cooperation, networks of these information processors are able to carry out the complex computations underlying higher cognitive functions, such as navigating the physical and social world and satisfying goals. Electroencephalography (EEG)—the technique used to measure ERPs—provides a method to study these neural networks online (during real-time processing) by making use of the physiological properties of computation in the brain.

Cooperative computation among neurons requires inter-neuron communication, and in the brain this is handled by electrical and chemical signaling. A signal sent between neurons can be either excitatory or inhibitory. If a neuron is excited to a large enough degree, it will send out electrical signals, called *action potentials*, which upon leaving the neuron are transformed into chemical signals that either excite or inhibit a next neuron. The excitation or inhibition of neurons is manifested by tiny voltage fluctuations (in the order of *microvolts; micro=1 per million*). If enough of these voltage fluctuations take place simultaneously, and with the same polarity (i.e., positive or negative, relative to a neutral reference point), they can be measured using electrodes placed on the scalp, which is what is referred to as EEG. A single EEG recording typically reflects thousands of neural processes in parallel. Most of these processes may be involved in sensory, cognitive and motor activities unrelated to language processing. When averaging over numerous similar EEG recordings time-locked to a specific (e.g., a linguistic) stimulus, this background activity is filtered out, and what is left reflects the neurophysiological activity as elicited by the stimulus. This stimulus-related activity is referred to as an Event Related brain Potential or ERP.

A typical ERP signal is a temporal sequence of negative and positive voltage deflections (relative to a pre-stimulus baseline), which are called *components*. A single ERP component is taken to index the neural activity underlying a specific computational operation carried out in a specific neuronal ensemble (Luck, 2005; Näätänen & Picton, 1987). Components vary in polarity (i.e., they are more positive or more negative than electrodes chosen as a reference), amplitude, latency, duration, and distribution over the scalp, suggesting that different components reflect distinct functional processes, possibly carried out in distinct cortical regions. This means that if two stimuli are processed differently to some degree, this difference might be apparent in the ERP responses that they produce.

Kutas & Hillyard (1980) were the first to see the significance of ERPs for the study of language processing. They presented subjects with sentences containing a final word that rendered the overall sentence meaning anomalous (‘He spread the warm bread with <u>socks</u>’), and contrasted the ERP signals evoked by these sentence-final words with those evoked by non-anomalous ones (‘He spread the warm bread with <u>butter</u>’). This contrast revealed that, relative to controls, semantically anomalous sentence-final words produce an increase in the amplitude of the so-called N400 component, a negative deflection in the ERP signal that starts around 200-300ms post-word onset, and that peaks at about 400ms. This N400-effect has been interpreted to reflect increased semantic integrative processing for anomalous relative to non-anomalous sentence-final words. An overwhelming number of studies have since investigated the factors that modulate the presumed semantic processes underlying the N400 component (see Federmeier & Laszlo, 2009; Kutas & Federmeier, 2011, for overviews). The general picture that has emerged from this work, is that N400 amplitude does not only increase in response to semantically anomalous sentence final words, but that it is in fact evoked by every content word in a sentence, reflecting how well this word fits with its prior context (Kutas & Hillyard, 1984; Kutas, Lindamood, & Hillyard, 1984).

Van Berkum (2012), in his overview on the electrophysiology of discourse and conversation, focused primarily on the N400 component. However, we believe that we should direct our attention to the other main language component, the 'P600', which we think is more pertinent to the investigation of communication and higher cognitive processing. To appreciate this shift in focus, we will first provide a brief introduction to the “Semantic Illusion” phenomenon, which has received a considerable amount of interest over the past decade (Kolk et al., 2003; Kuperberg et al., 2003; Hoeks, Stowe, & Doedens, 2004; Kim & Osterhout, 2005; Nieuwland & Van Berkum, 2005; Van Herten et al., 2005, 2006; Kuperberg, 2007; Bornkessel-Schlesewsky & Schlesewsky, 2008; Stroud & Phillips, 2012; Brouwer et al., 2012; Chow & Phillips, 2013).

2.2. The “Semantic Illusion” phenomenon

For a long time, N400 amplitude has been assumed to reflect *semantic integration* (Osterhout & Holcomb, 1992; Brown & Hagoort, 1993; Chwilla et al., 1995; Hagoort & Van Berkum, 2007; Hagoort et al., 2009; Wang et al., 2009; Lotze et al., 2011). On this view, the N400 component indexes the *compositional*, or *combinatory* processes involved in integrating the meaning of an incoming word with the semantic representation of its prior context. However, since a few years, a different perspective on the N400 component, the *memory retrieval* hypothesis has gained influence (Kutas & Federmeier, 2000; Van Berkum, 2009). Under the retrieval view, N400 amplitude does not reflect integration (or any other kind of combinatorial processing), but rather the *retrieval* from long-term memory of the lexical and semantic knowledge associated with a word. Retrieval is facilitated if the (lexical and conceptual) knowledge associated with a word is pre-activated by its prior context, leading to a *reduction* of N400 amplitude. Pre-activation occurs through lexical priming (explaining N400 modulations in word-pairs), as well as through message-level and script priming from the context (e.g., e.g., St. George, Mannes, & Hoffman, 1994; Van Berkum, Hagoort, & Brown, 1999; Van Berkum, Zwitserlood, Brown, & Hagoort, 2003; Otten & Van Berkum, 2007; Ditman & Kuperberg, 2007). According to the memory retrieval account, the N400-effect observed by Kutas & Hillyard (1980) reflects the fact that the conceptual knowledge associated with the non-anomalous sentence-final word *butter* is pre-activated through both lexical priming (*butter* fits well with the words *bread* and *spreading*), and message-level or script priming (for instance, *spreading* and *bread* together easily evoke a 'breakfast' scenario stored in long term conceptual memory, in which things like *butter*, but also jam, eggs, coffee etc. are very likely to occur), whereas the conceptual knowledge associated with the anomalous word *socks* is not pre-activated. As a consequence of this difference in pre-activation, the conceptual knowledge associated with *butter* is more easily retrieved (because it is pre-activated) than that associated with *socks*.

It has proven quite difficult to decide between these competing interpretations of the N400 component. However, a set of studies investigating so-called 'Semantic Illusion' sentences eventually proved crucial for this decision. Hoeks et al. (2004), for instance, tested the processing of sentences in which two semantically plausible arguments for a verb appear in the wrong order (e.g., 'De speer heeft de atleten <u>geworpen</u>'; lit: 'The javelin has the athletes <u>thrown</u>'), rendering the overall sentence meaning semantically anomalous. Relative to a sentence in which the arguments appear in canonical order (e.g., 'De speer werd door de atleten <u>geworpen</u>'; lit: 'The javelin was by the athletes <u>thrown</u>'), the semantic integration and memory retrieval hypotheses make opposite predictions regarding N400 amplitude at the critical verb *thrown*. The semantic integration hypothesis predicts an N400-effect at the critical word *thrown*, reflecting increased difficulty in integrating its meaning with the preceding context. The memory retrieval hypothesis, on the other hand, predicts no N400-effect at the critical verb, as in both the reversal and the control condition, the conceptual knowledge associated with the critical verb *thrown* should be equally easy to retrieve; in both conditions, *thrown* is primed lexically through *javelin* and *athletes*, as well as through world knowledge (throwing a javelin is a normal thing to do for an athlete). Consistent with the memory retrieval hypothesis, Hoeks et al. observed no N400-effect at the critical verb.

Proponents of the semantic integration hypothesis have argued that the absence of an N400-effect can be explained by assuming that participants made a coherent semantic representation of the sentence without reference to its syntactic structure. That is, they assume that through an independent semantic analysis, readers were effectively tricked into a `Semantic Illusion', leading them to believe that the stimuli made perfect sense. A few hundred milliseconds later, however, the processor did somehow find out that this interpretation is incorrect. This is reflected in the increase of P600 amplitude, a positive deflection in the ERP signal that, on average, reaches its maximum around 600ms. In some of these 'multi-stream' models—all of these models include an independent semantic analyzer and an algorithmic/syntactic stream, and sometimes additional processing streams as well—the P600-effect is associated with effortful *syntactic* processing in order to make sense of the utterance (see Gouvea et al., 2010, for an overview of syntactic interpretations of the P600). Other multi-stream models view the P600 as indexing the resolution of a conflict between syntactic and semantic streams (Kim & Osterhout, 2005; Kolk et al., 2003; Van Herten, 2005, 2006; van de Meerendonk et al., 2009, 2010; Vissers et al., 2006, 2007, 2013; Ye and Zhou, 2008; Kuperberg, 2007; Bornkessel-Schlesewsky & Schlesewsky, 2008; Kos et al., 2010). However, in an extensive review, Brouwer et al. (2012) showed that none of the complex multi-stream models can actually explain all of the relevant data. They argue for a single stream architecture, the Retrieval-Integration account, that is based on different assumptions of the functional significance of the N400 and the P600.

Brouwer et al. argue that the retrieval account of the N400 component offers the most parsimonious explanation, as the absence of an N400-effect in reversal anomalies can easily be explained as lexical and message-level priming; no special semantic stream is necessary (see Stroud & Phillips, 2012; Chow & Phillips, 2013, for similar arguments). However, if the N400 component does not reflect compositional or combinatorial semantic integration processes, then where in the ERP signal do these processes show up? Given that semantic integration is essential for the comprehension system, one would expect it to be reflected in the electrophysiology of language processing. Brouwer et al. suggest that these integrative semantic processes are indexed by the P600 component. They hypothesize that the P600 is not a single component, but actually a family of late positivities that reflect the word-by-word construction, reorganization, or updating of a mental representation of what is being communicated, or "MRC".

An MRC is very similar to a 'mental model' (Johnson-Laird, 1983) or 'situation model' (Kintsch, 1998; Zwaan & Radvansky, 1998). The difference with these models is only of degree: whereas mental models and situation models represent interpretations of all types of situations, be they linguistic or otherwise, an MRC is a representation of how a person interprets his current *communicative* situation. A communicative situation, such as a conversation, can be seen as containing a number of different aspects: a representation of the current utterance, a representation of the discourse/conversation until now, a representation of the 'face' of self and of the other interactants, a representation of the language user's *private* representation of self and others, including their long-term and short-term (conversational) goals. All of these aspects are assumed to be represented in the current MRC of an individual involved in a conversation. And adapting this MRC leads to a increase in P600 amplitude.

Summarizing, from the perspective of the Retrieval-Integration account, the P600 component is modulated by each word in a sentence as the lexical information activated by a word is integrated into the current mental representation, resulting in an updated representation of the input given thus far. An important consequence of this view is that language comprehension proceeds in biphasic N400-P600 cycles. The retrieval of the conceptual information associated with a word modulates the N400 component, and the integration of this information with an unfolding MRC into an updated representation, is reflected in P600 amplitude. Importantly, we propose that these two components are responsive to general cognitive processing, and that neither of them is language-specific: Every meaningful stimulus will cause the retrieval of the features in long term memory that are associated with that stimulus, and thus, every meaningful stimulus will evoke an N400. Likewise, creating a new representation of a (linguistic or non-linguistic) situation, or any change in that representation is hypothesized to lead to an increase in P600 amplitude.

2.3. The brain basis of the Retrieval-Integration account

Retrieval-Integration cycles provide a general and parsimonious account of the elicitation patterns of the N400 and the P600 component. This sheds light on the *how* and the *when* of comprehension, but not on the *where*, which is indispensible information for creating and supporting a viable model of language comprehension. ERPs have a poor spatial resolution, which makes it very difficult to pinpoint where an observed ERP signal was generated in the brain. Hemodynamic-based (“blood-based”) neuroimaging techniques, by contrast, such as fMRI (and PET), can be used to localize cognitive processing, but have a poor temporal resolution. This might suggest that electrophysiological and hemodynamic methods provide complementary information, which we would ideally like to combine to arrive at a viable neurobiological model of language comprehension. However, due to the fundamentally different nature of electrophysiological and hemodynamic measurements, it is not immediately clear how they can be combined; that is, due to their differences in spatial and temporal resolution, it is often impossible to simply align them for a given experimental paradigm (cf. Lau et al. 2008).

A more promising strategy, therefore, is to start from the processes assumed to be reflected in the different language-related ERP components, and to map these onto cortical areas or networks that could host them. On the basis of this “process alignment strategy”, Brouwer and Hoeks (2013) have recently proposed a minimal functional-anatomic mapping of the Retrieval-Integration account that focuses on the anatomical and computational *epicenters* (cf. Mesulam, 1990, 1998) or *hubs* (Buckner et al., 2009) of the language network. Building upon several large-scale reviews on the cortical organization of the comprehension system (Dronkers et al., 2004; Turken and Dronkers, 2011, Bookheimer, 2002; Lau et al., 2008; Friederici, 2002, 2011; Hickok and Poeppel, 2004; 2007; Vigneau et al., 2006; Shalom and Poeppel, 2008), they identified the left posterior Middle Temporal Gyrus (lpMTG; Brodmann Area, BA, 21; the green area in Figure 1) as an epicenter that mediates the lexical retrieval processes underlying the N400 component. That is, the lpMTG is assumed to mediate the mapping of word form to conceptual representations, which are stored in a distributed manner across the association cortices (cf. Elman, 2004, 2009; Pulvermüller, 1999, 2001; Rogers, 2004). As such, the focus of activity reflected in N400 amplitude is assumed to take place in the lpMTG, but the full range of activity reflected in the N400 component also includes the activation of conceptual features in the association cortices. The integrative processes underlying the P600 component, in turn, are assumed to be mediated by the left Inferior Frontal Gyrus (lIFG; BA 44/45/47; the yellow area in Figure 1), which is a neuroarchitecturally complex, highly parcellated area (Friederici, 2011; Amunts et al., 2010; 2012). Brouwer and Hoeks suggest that this anatomical parcellation may underlie a fine-grained functional topology of the lIFG (see also Hagoort, 2005; Friederici, 2011), in which different parcels of the area may carry out different sub-processes involved in MRC construction, thereby unifying ongoing debates about the functional role of the lIFG (see Grodzinsky & Santi, 2008; Rogalsky & Hickok, 2011, for overviews). On this view, the mental representation of what is being communicated is maintained in (or: its activity is coordinated by) the lIFG. Critically, linking the P600 to the lIFG suggests that characteristically different P600s in terms of electrophysiological properties like onset, duration, amplitude, and scalp distribution, which Brouwer et al. (2012) assume to reflect different sub-processes of MRC construction, may have an anatomical basis in different, but potentially overlapping parcels of the lIFG. Like the lpMTG and the N400, the lIFG is assumed to serve as an epicenter that is host to the focus of activity reflected in P600 amplitude, but the full range of activity underlying the P600 component may include activity from adjacent areas as well.

The retrieval epicenter (lpMTG) and the integration epicenter (lIFG) are wired together by means of two white matter pathways, a dorsal pathway (including the classic *arcuate fasciculus* and the *superior longitudinal fasciculus*) and a ventral pathway (including the *extreme fiber capsule system*, the *uncinate fasciculus,* and the *inferior* and *medial longitudinal fasciculi*), the precise functions of which are still much debated (Friederici, 2009, 2011; Baggio and Hagoort, 2011; Hickok and Poeppel, 2004, 2007; Tyler et al., 2011; Weiller et al., 2009). Consequently, it is as of yet not possible to choose which of these pathways supports the connection of information retrieved in the lpMTG to the lIFG for integration, and which pathway serves to connect the updated MRC back from the lIFG to the lpMTG, providing a context for upcoming words. The presence of these pathways, however, indicates that there are at least two pathways supporting Retrieval-Integration cycles.

Putting the above together, we can walk through a typical functional-anatomic Retrieval-Integration cycle. An incoming word reaches the lpMTG via either the auditory cortex (ac; see Figure 1) or the visual cortex (vc), depending on whether the linguistic input is spoken or written. The lpMTG then mediates the retrieval of the lexical information associated with this word from the associations cortices, where it is stored in a distributed manner. This process generates the N400 component of the ERP signal, the amplitude of which corresponds to the ease of retrieval. The retrieved lexical information is linked up to the lIFG via either the dorsal (dp) or ventral pathway (vp), where it is integrated with its prior context (the prior MRC), into an updated representation of what is being communicated (an updated MRC). The extent of work required to get this updated representation of what is communicated, is reflected in P600 amplitude. Meaning aspects of the updated representation are fed back from the lIFG to the lpMTG via the dorsal or ventral pathway, which provide a context for possible upcoming words, upon which a new Retrieval-Integration may start. Figure 1 provides a schematic overview of a Retrieval-Integration cycle.

The functional-anatomic mapping of the Retrieval-Integration account proposed by Brouwer and Hoeks (2013) is not intended to be a full-fledged neurobiological model of language comprehension, but as the extendable *core* of the comprehension system. As such, it can serve as a starting point for research into the coupling of brain anatomy and electrophysiology, as a step towards a neurocognitive model of communication.

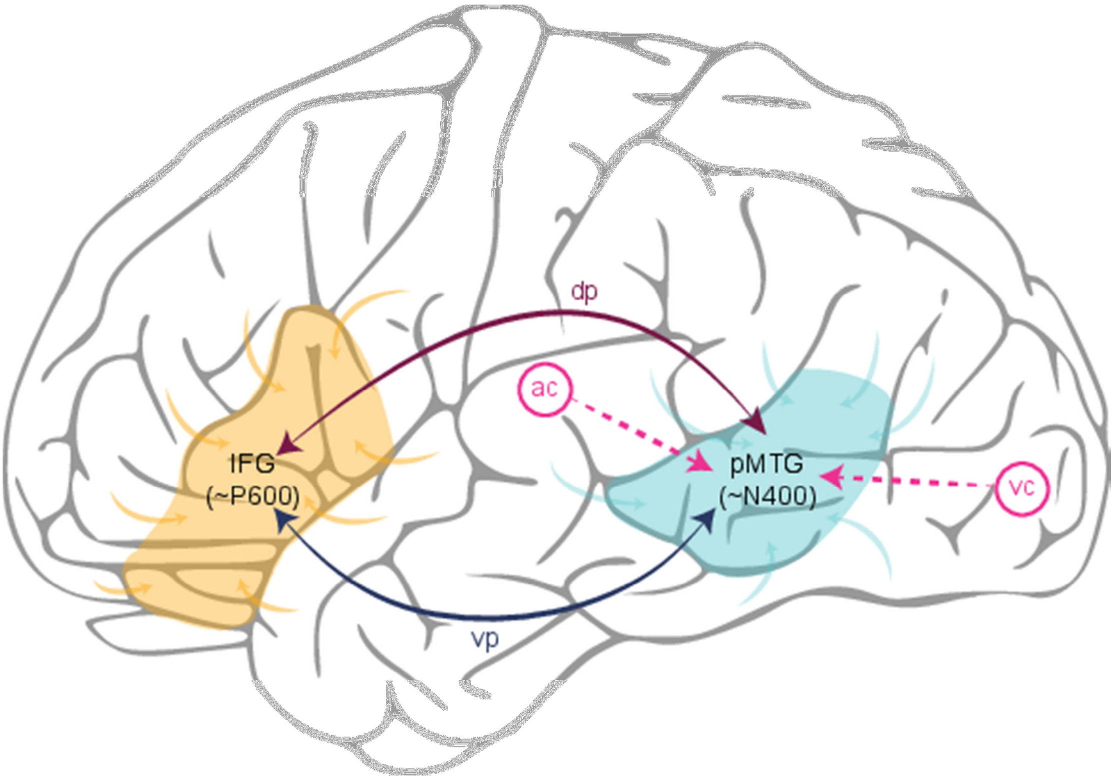

Figure 1: Schematic overview of a typical Retrieval-Integration cycle in the left hemisphere. Depending on whether the linguistic input is spoken or written, an incoming word reaches the left pMTG via either the auditory cortex (ac) or the visual cortex (vc), respectively. The pMTG then retrieves the lexical information associated with a word from the association cortices, which generates the N400 component. Via the dorsal pathway (dp) or the ventral pathway (vp), the retrieved information is connected to the left IFG, where it is integrated with its prior context (the prior MRC), into an updated representation of what is being communicated (an updated MRC). This integrative processing generates the P600 component. Finally, the updated MRC is connected back to the pMTG via one of the pathways, providing a context for upcoming words, upon which a new Retrieval-Integration cycle may start.

3. The Electrophysiology of Discourse and Conversation

Conversation is without doubt the most natural form of human interaction. Some have likened it to a dance, where two partners together carry out a complex pattern of co-ordinated movement. However, this metaphor is perhaps a bit too friendly, and also a bit misleading. The dance metaphor namely suggests that the two partners in the interaction are equal, and that the interaction is fun. While that may be true in some cases, it certainly is not in others. If conversation is to be considered a dance, it is one where often enough one of the dancers is dominant, and makes the other dancer go somewhere, instead of just giving a good show. But what is more, conversation isn't fun, it's serious business, an essential part of human social functioning.

3.1. Social Aspects of Communication

As biological beings, we humans are born with a set of goals, the primary goal being procreation (some would formulate it slightly differently: our *genes* have goals, namely to spread, we are 'survival machines' for our genes; cf. Dawkins, 2006). In order to reach the goal of procreation, evolution has provided us with internal drives that keep us alive long enough to procreate and take care of our offspring. Brain research has suggested that these motivators are implemented in specific areas deep in the brain, such as the hypothalamus and other parts of what researchers have sometimes referred to as the Limbic System. These motivators (hunger, thirst, sex drive, aggression, etc.) create a web of distal and proximal goals, hierarchically ordered in sub-goals, sub-sub-goals, and so forth. In order to reach these goals we have to negotiate the physical world, but because we are also *social* animals, we will encounter our conspecifics while trying to satisfy our goals, so we will need to negotiate the social world as well. Furthermore, some of our goals lie entirely in the social realm, goals like being recognized, and valued. So what separates us from more solitary animals is that we are not alone in the world, we have a public, we are 'seen', every moment of the day, even if there is no one present. And that is where communication comes in: we can get what we want only by interacting with our fellow human beings, as they are everywhere.

The ubiquity of fellow human beings means that there is a pressure to adapt our behavior to certain social rules that have developed to minimize within-group competition, while maintaining high chances of individual survival. Being a social animal will often mean that we have to inhibit our first, impulsive original plans, and adapt them to suit the requirements of the social situation. These impulsive behaviors may involve impulses to mate with a certain individual, to grab food that is available, to drink, to hit someone that comes too close or that shows interest in your piece of food. The social rules that have been created to regulate these impulses to minimize conflict are sometimes highly complex, and take a long time to learn (you need to be with children only a couple of minutes to appreciate the latter fact). Some of these social rules can be considered a sort of 'baseline', and preclude, among other things, showing behavior in public that has to do with bodily functions (belching, farting, scratching, nose picking, grunting, etc., with the exception of *eating*), but also include rules regarding clothing, posture, hairdo, gait, bodily proximity, duration of eye contact, etc. The majority of social rules, however, seem in place to govern active *interaction*. The whole set of social rules regulating behavior, which varies from culture to culture, can be called "politeness", subsuming "linguistic politeness". Linguistic politeness rules specifically concern what to say and how to say it. Brown and Levinson (1987) argue that the rules for formulating for instance requests to another person are not random and haphazard, but are centered around 'directness'. As a general rule, extreme directness ('bald on record'), as in "Leave this room", is only allowed under very specific circumstances, such as when there is an emergency, or when the power distance between interactants is very high. In all other cases, more indirect utterances are required, where requests are embedded in lexical material, where reasons are given and where the speaker apologizes ("I am really sorry, but could you please leave the room, we have to clean the floor").

We have many social goals such as getting what we want from people (through persuasion). However, one of our most important social goals is what is sometimes called 'impression management' (Schlenker, 1980), a concept that is derived from the notion of 'face' introduced by Erving Goffman (1959; 1967), how to create the desired image of yourself in the public that is currently present. This impression can be said to have an upper limit, which is the representation we desire, that is, how we want to seem (to this end we also use postures, clothes, and other accessories, such as cars, houses, etc., see Goffman, 1959), and we want to avoid a perhaps more general lower limit, which is the 'neutral' baseline mentioned above. According to Goffman (1959), each time we are in a social situation, we choose a 'stance' or 'role', for instance, one in which we are very successful in our job, our family is doing well, and we are happy, but also friendly and sympathetic—all of these are of course idealizations of our real mammalian selves. Effectively, we thus have at least two types of interactant representations that have to be taken into account in a given interaction, our own *public* face, and the public face of the interlocutor, but also the two corresponding *private* representations of self and other at play that may overlap with the public face representations, but that are certainly not identical.

Most people are surprisingly good at face management during conversation. This is no small feat, because it requires handling at least four different representations (public face of the interactants, plus the private representations including the interactants' goals), a representation of the current situation, and a set of complex social rules, including the specific and quite intricate rules for conversation. But we all know people who either seem to lack the social knowledge required to take the face of the interactant into account, or who simply do not care too much about the consequences that face damage might have, either regarding their own face, or the face of others. So there are individual differences in social sensitivity and social knowledge (which will most often be correlated) that can increase the chance of face threatening situations. Sometimes face damage is the result of clumsiness of you yourself, or your fellow interactant. However, it may also be intentional, motivated by aggression, anger, disappointment, and other emotions (cf. Culpeper, 1996; Bousfield, 2008). This illustrates that the rules of social engagement are essentially normative: they can be broken, though there will be consequences.

Despite the importance of the social aspects of language use we just discussed, there have been no electrophysiological studies on how social aspects of conversation are processed. There is only one study by Hoeks, Schoot, Taylor & Brouwer (in prep.), who looked at participants 'overhearing' *visually* presented mini-dialogues. One of the protagonists in the mini-dialogue asks the other person for a favor, or asked a mere knowledge question. Social rules of conversation tell that a blunt "No", without giving reasons or apologizing is not acceptable, even when people know each other really well (in the experiment, participants were told that the mini-conversations were between two people who were in a relationship).

Request condition

partner 1: "Could you please put out the garbage tomorrow?"

partner 2 (blunt): "No."

partner 2 (softened): "No, I'm sorry, I have to leave early"

Knowledge Question condition

partner 1: "Did you know that John will put out the garbage tomorrow?"

partner 2 (blunt): "No."

partner 2 (softened): "No, I'm sorry, I didn't know"

Hoeks et al. found a significant positivity for the blunt NO ("No." with a period), as compared to the softened NO ("No," with a comma, later followed by an apology) for both requests and knowledge questions. In the request condition, however, the positivity started earlier, had a broader scalp distribution, and was of a larger magnitude than in the knowledge question condition. These positivities were interpreted as P600 effects reflecting the reorganization of the MRC as a result of less than polite linguistic behavior. Part of the processing may have involved the updating of speaker representation—"this person saying "no" is rude, I better be on my guard".

To what extent this knowledge about the speaker is represented as integral part of the developing discourse representation, or relatively separately, is a matter for future research. We do know from fMRI research that the application of social rules most likely involves areas in the frontal cortex (i.e., Medial Prefrontal Cortex, see Barbey and Grafman, 2011). In addition, studies have identified the bilateral Temporal Parietal Junction (i.e., in both hemispheres) as an area that may be specifically involved when reasoning about the intentions of persons in interaction, which makes it a good candidate brain area supporting a separate speaker representation (Decety and Lamm, 2007; Bara, Ciaramidaro, Walter, & Adenzato, 2011). It will have to be established how a representation of speaker fits into the anatomical core network of language processing that we have described earlier.

Returning to the experiment on politeness described above, part of the processing difficulty that was found for bluntly saying NO may in some sense also be *pragmatic*; what did the person want to communicate by being blunt? That is, why did the person refrain from offering an apology, or some kind of a motivation for the refusal? This kind of inference, where the intended meaning of the speaker is recovered, will be further discussed in the next section.

3.2. Pragmatic Aspects of Communication

Only very few experiments on language comprehension featured real speakers. Generally, participants just read isolated sentences or unrelated texts from a screen, and never have to wonder what the speaker would actually mean by these sentences or texts, as of course there was no one there to mean something. However, in real life, language is uttered with a goal -- speakers want to get a certain message across -- and listeners try their best to get at that message. Utterances that are fully unambiguous do not exist. This means that listeners will have to engage in effortful processing to get a grip on what the speaker meant to communicate. This processing can stop once the listener managed to create a representation of the conversation so far that is coherent. Coherence in conversations is achieved by three means: 1) establishing reference, 2) using information structural cues to identify the new information and how and where it fits in the larger discourse, and 3) using inference to establish what the speaker meant to communicate, or when there are problems with (1) or (2). Precisely because we *know* that a speaker has a goal, and therefore wants to be coherent, listeners operate on the basis of the evidence presented in the utterance, on the basis of the representation of the situation, and on the basis of the knowledge of the speaker (including what is known or might be surmised about his or her goals), to figure out what is meant.

3.2.1. Establishing Coherence—Reference

Every time a noun phrase (the baker), a name (John) or a pronoun (he) is encountered, the listener must determine the entity this expression refers to: its *antecedent*. Retrieving the conceptual features associated with this referring expression seems to be a prerequisite for finding the right antecedent. Full nouns (e.g., ‘baker’) will require a more extensive retrieval process than either names or pronouns, as these latter are rather ‘knowledge lean’. For instance, in isolated sentences such as “John hit Mary”, names such as ‘John’ and ‘Mary’ contain very little information. Similar to pronouns, such names will hardly activate more features than those regarding number (singular versus plural) and gender (grammatical and/or biological). However, if the name refers to a known figure, either from reality (‘Bram Stoker’) or from fiction (‘Count Dracula’), there is more information about this person in long-term memory that can be retrieved. Note that these retrieval processes can be expected to be especially extensive when nouns or ‘real’ names are mentioned in a discourse for the first time; retrieval effort will be much reduced for repeated mentions. After this meaning activation, the processor can look for a matching antecedent.

Van Berkum, Brown, & Hagoort (1999) were the first to look at the electrophysiological correlates of processing reference. They presented participants with sentences that contained a singular definite NP, like “The dean told the lecturer […]”, embedded in a story that had either introduced a single referent (one lecturer) or two equally plausible referents (two lecturers). Relative to the one-referent condition, the critical NP in the ambiguous, two-referents condition was found to produce a sustained negativity that was broadly distributed over the scalp, but with a distinct frontal focus, starting at about 200ms post word onset. The increase in the amplitude of this sustained negativity has been labeled the *Nref effect*, and has been taken to reflect the increased difficulty of establishing reference when there are multiple possible antecedents. This interpretation is supported by the finding that the Nref effect disappears if the ambiguity is eliminated before the criticial NP, for instance, by having one of the referents leave the scene (Nieuwland, Otten, & Van Berkum, 2007).

Van Berkum (2009) suggests that the Nref effect is not a response to an anomaly, but “*… the brain’s natural inclination to immediately relate every shred of new information to what is known already.*” (p. 287). In line with that, we would like to hypothesize that each referring expression elicits an Nref, a negative deflection of the ERP signal that reflects the search for the right antecedent. We need more research to provide a detailed view of the Nref as a *component*, but we already know a number of things about the Nref as an *effect* (see Van Berkum, Koornneef, Otten, & Nieuwland, 2007, for review). For one, it is often broadly distributed over the scalp, though quite pronounced frontally. Also, the Nref effect often appears as a sustained negativity, although, as we will argue below, it can sometimes be very difficult to judge whether we are dealing with a sustained effect, or merely a shifted waveform that did not return to baseline. Furthermore, the extent of the Nref effect may depend on the ease with which the reference problem can be resolved. In the case of a global ambiguity (e.g., "Robert and Daniel were talking, and he …"), the processor may have a hard time finding the right antecedent for 'he', leading to sustained processing difficulty; in other cases, the negative shift may appear to be more 'phasic'. And finally, as far as latency is concerned, it has been claimed that the Nref appears no earlier than 300-400ms post onset, but the difference waves presented in Van Berkum et al. (1999; p. 157, Fig. 1b) suggest that the original Nref effect already starts around 200ms after the onset of the ambiguous word. It is highly likely that the Nref as a component starts even earlier.

It seems plausible that the processor first activates salient knowledge about a given referring expression before being able to find the most plausible antecedent. As we argued above, this activation of relevant knowledge will be reflected in the amplitude of the N400, and referent resolution in the Nref. If we compare the latencies of the ERP components involved (i.e., the N400 for meaning activation and the Nref for establishing reference), these two processes seem for a large part to be running in parallel. Reference assignment thus does not seem to wait for meaning activation to have completed. This makes it difficult to separate the two components (and even raises the question whether they are all that different, except for the representational system—conceptual memory or current discourse representation—that is consulted).

Summarizing, we assume that as soon as referring expressions are encountered, their lexical semantic features will be activated, giving rise to an N400, and the right antecedent will be sought, giving rise to an Nref. We do expect considerable differences between nouns, names and pronouns. As we pointed out above, nouns (and 'real' names) will require the most extensive retrieval from long term memory, and will thus elicit the largest N400 amplitude. The associated Nref is most probably running in parallel with, or slightly behind the N400, and will thus overlap with it. In contrast, names and pronouns have relatively little lexical and semantic information associated with them, so the retrieval stage will probably be rather restricted, and thus, the processing of names and pronouns will most likely be most pronounced in the Nref component. These assumptions mesh with the Retrieval-Integration account of language processing presented above. The RI account has identified two core systems that are both functionally and anatomically distinct: the semantic memory system, with a hub in the temporal lobe, containing all lexical and world knowledge, and a working memory system involved in creating, adapting and maintaining a representation of what is currently communicated, with a hub in the inferior frontal lobe. It makes sense that in the interpretation of nouns, both of these representations are accessed to a certain degree. The same is likely true for the interpretation of names and pronouns, but in this case the balance is skewed towards accessing the situation model/MRC. We propose that searching the situation model leads to an Nref, whereas searching the semantic memory system leads to an N400. This is in line with Kotchoubey's (2006) account of the relation between component polarity and cognitive processing. On that account, negative shifts (N400, Nref) reflect *preparatory* processing and search, whereas positive shifts (P600) reflect *combinatory* processing and synthesis. An fMRI study by Nieuwland, Petersson, and Van Berkum (2007) showing that referential processing leads to activation of frontal brain areas provides further support of this hypothesis. So for content nouns (and 'real' names), we expect both N400 and Nref, for pronouns and 'empty' names, we expect an Nref, and hardly any modulation of the N400. This is consistent with findings from a recent study by Taylor and colleagues (Taylor, Stowe, Redeker & Hoeks, in prep; Taylor, 2013). They presented participants with spoken mini-dialogues like the following:

A: "Lisa lost the chess tournament"

B: "Oh?"

A: "The teacher congratulated <u>her</u>."

Compared to dialogues where Lisa won the tournament, there was no N400 effect on the pronoun, even though its antecedent was unexpected, as it is strange to congratulate Lisa if she just lost a tournament; a P600 effect was found instead.

To be clear, there have been reports of "N400 effects" for names and pronouns. Indeed, there is a comprehensive literature concerned with the so-called *Repeated Name Penalty*. Ledoux, Gordon, Camblin, and Swaab (2007), for instance, found longer reading times for a repeated name in an eye-tracking study using sentences such as: "At the office, <u>Daniel</u> moved the cabinet because <u>Daniel</u> needed room for the desk". Repeating the name (Daniel) to refer to the same antecedent is infelicitous, and leads to processing difficulty (hence the 'Penalty'). In a replication of this experiment with ERPs reported in the same paper, Ledoux et al. found a negative shift for the repeated name, as compared to a felicitous control sentence ("At the office, Daniel and Amanda moved the cabinet, because Daniel needed room for the desk"). They interpret this negativity as an N400 effect, but in the light of our previous discussion, it is more likely to have been an Nref effect. Indeed, a close look at the data from Ledoux et al. reveals that the negativity is broadly distributed over the scalp, and clearly visible at frontal electrodes, a pattern which is very similar to the Repeated Name Penalty effect found in an earlier ERP experiment (Swaab, Camblin, & Gordon, 2004). The auditory version of the same experiment also produced a negative shift that was actually largest at frontal electrodes (Camblin, Ledoux, Boudewyn, Gordon, & Swaab, 2007). Thus, it seems that if a referring expression is 'marked' in some way (using the full form 'Daniel' when a reduced form, the pronoun 'he', is called for), it is more difficult to find the correct referent, leading to an increase in Nref amplitude. Interestingly, the Camblin et al. data show that if the name is not a marked form, as in the felicitous control sentence, the negativity is actually reduced as compared to a control sentence, indicating that finding the antecedent has become easier. This repetition effect on the Nref mirrors the well-known repetition effect on the N400 (Kutas & Federmeier, 2011).

Whether we can categorize a given effect as an Nref or as an N400 of course depends crucially on the estimated onset and scalp distribution that are observed. Unfortunately, though, onset and scalp distribution are also known to vary with materials used, mode of delivery (auditory versus visual), and the individual differences in functional and anatomical organization of language in the participants. We will come back to this issue in the discussion section, as it is a general problem that affects the interpretation of other components and effects as well.

Until now, we have discussed cases where the antecedents are present in the discourse model/MRC of the listener. When there is not yet an antecedent, the listener must create a brand new discourse entity. In case of definite referring expressions, the definiteness acts as a signal to listeners that they are supposed to have an antecedent for this expression (i.e., the 'definiteness presupposition'; Russell, 1905). If that is not the case, listeners may have to accommodate the antecedent in the current discourse representation. Accommodation of discourse entities has been shown to lead to P600 effects. For instance, Burkhardt (2006) compared the following discourse fragments:

Tobias was having a chat with Nina. He said that the conductor was …

Tobias visited a conductor in Berlin. He said that the conductor was …

Only in the second fragment is the definite expression "the conductor" from the second sentence properly introduced in the first sentence, namely as an indefinite NP ("a conductor"). In the first discourse fragment, the conductor from the second sentence is not introduced, leading to a P600 effect, presumably due to accommodation.

Sometimes, the antecedent for a referring expression can only be identified through so-called "reference transfer" (cf., Nunberg, 1979). Schumacher (2011) examined the processing of mini-discourses, in which the second sentence contains a semantic anomaly (e.g., 'The doctor asks his assistant again who called that early. The assistant responds that the hepatitis had called that early'). In its literal sense, the critical NP 'the hepatitis' is a poor agent for the verb 'call', rendering the sentence anomalous. However, this anomaly disappears if the reference of 'the hepatitis' is *transferred* from its literal meaning (e.g., liver inflammation) to a referent that is contextually associated with it (e.g., a patient suffering from liver inflammation). Relative to a mini-discourse in which no transfer of reference was required (e.g., 'The doctor asks his assistant again who called that early. The assistant responds that the therapist had called that early'), Schumacher found that the critical NP `the hepatitis' produced a P600-effect, which she interpreted as reflecting enriched composition.

There is also the possibility that there are antecedents present, but none of them is available for the referring expression that is used. For instance, Van Berkum et al. (2007) review a number of studies looking at sentences such as "Anna shot at Linda as he …", where there is no matching antecedent. Compared to the control sentence "David shot at Linda as he …", the failure to find an antecedent led to a P600 effect. Thus, the failure to find a matching referent leads to immediate interpretation problems.

In conclusion then, we propose that each referring expression elicits an Nref, from searching the discourse representation or MRC. Marked delivery, for instance by using a full NP where a pronoun is required, will lead to in increase in the Nref amplitude, reflecting the extra effort needed to find the correct antecedent. In addition to an Nref, all referring expressions will elicit an N400 due to the activation of lexical semantic information -- contained in the conceptual memory system -- though this is most pronounced for nouns and ‘real’ names. If establishing reference turns out to be impossible, or leads to an implausible interpretation, a P600 will ensue, reflecting the reorganization of the MRC. A P600 may also appear in the absence of serious problems like the ones mentioned above (i.e., persistent reference failure, or semantic anomaly), namely when a discourse entity needs to be accommodated or when the referring expression needs some ‘pre-processing’ before the antecedent can be successfully identified.

3.2.2. Establishing Coherence—Information Structure

In discourse, and especially in conversation, coherence is achieved not only through referential links, but also via the *information structure* of an utterance, and more specifically through the information structural dependencies between an utterance and its preceding context. Information structure can be broadly described as the way the information contained in an utterance is segmented (cf. Chafe, 1976). In general terms, the informational content of an utterance can be divided into information that is backgrounded, also termed *topic*, or ‘given’, and information that is in *focus,* also termed ‘comment’, or ‘new’. The way in which the informational status of these different parts of the message is signaled varies per language. For instance, in languages like English and Dutch, prosody plays an important role in the marking of topic and focus: the topic is deaccented, and the focus part of the message receives a pitch accent. Other languages, such as Italian and French, predominantly use more structural means, such as *clefting* and word-order variations to indicate focus structure (Lambrecht, 1994). Marking the information structure of an utterance enables the listener to know which aspect of the message is meant as the ‘real’ information, and what part of the current discourse representation should serve as the ‘attachment site’ for this information.

The importance of information structure becomes apparent if information structure cues are *misplaced*. Quite a few studies have looked at what happens if backgrounded information is treated as new, or new information is treated as if it were already known (e.g., Bornkessel, Schlesewsky, & Friederici, 2003; Cowles, Kluender, Kutas, & Polinsky, 2007; Magne, Astésano, Lacheret-Dujour, Morel, Alter, & Besson, 2005; Heim & Alter, 2006; Wang, Hagoort, & Yang, 2009, Wang, Bastiaansen, Yang, & Hagoort, 2011, Li, Hagoort, & Yang, 2008, Li, Yang, & Hagoort, 2008, Hruska & Alter, 2004; Toepel & Alter, 2004; Toepel, Pannekamp, & Alter, 2007, Hruska et al., 2001; Dimitrova et al., 2012). For instance, Dimitrova, Stowe, Redeker, and Hoeks (2012) looked at spoken mini-dialogues where in some conditions, the topic of the target sentence sometimes received a pitch accent (superfluous accent), whereas in other conditions, the focus element sometimes remained unaccented (missing accent).

> Q: Did the club give a bonus or a fine to the player?
> #A: The club gave a <u>bonus</u> to the PLAYER. (missing accent on *bonus*)
> A: The club gave a BONUS to the player.

> Q: Did the club give a bonus to the player or to the trainer?
> #A: The club gave a <u>BONUS</u> to the player. (superfluous accent on *bonus*)
> A: The club gave a bonus to the PLAYER.

Both missing and superfluous accents were shown to lead to P600 effects, indicating problems in creating a coherent MRC. In addition, the superfluous accent condition also showed a long-lasting right-lateralized negativity. Importantly, in this study, and also other studies reviewed here, treating background information as new was operationalized by adding a pitch accent to the noun of the topical NP (here: 'a bonus'). As we have seen in the studies on the Repeated Name Penalty discussed above, marked delivery in the form of an over-specification ('Daniel' instead of 'he') leads to increased search in the situation model, causing an increase in Nref amplitude. Accenting a noun that should not be accented according to information structure rules could be seen as a marked delivery as well. This could explain why Dimitrova et al., but also other studies, found a negativity. Dimitrova et al. suggested that this negativity may have been an N400 effect, but we would like to entertain the possibility that the negativity was not an N400 effect, but an Nref effect, instigated by the marked delivery of the referring expression. If we look at the relevant waveforms in Dimitrova et al. (2012, fig. 5), we can see that the negativity starts around 200 ms post onset, and goes on for quite some time (at some electrodes even until after 1000 ms post onset) and is also present at frontal electrodes.

It is important to note that in contrast to many of the earlier studies, Dimitrova et al. did not use a prosodic judgment task, precisely because they hypothesized that such a task might interfere with the normal processing of the mini-dialogues. They were concerned that instead of focusing on the meaning of the exchange, participants' attention will be directed to categorizing the stimulus, and making a decision as to whether it is prosodically and contextually well-formed. These kinds of task-induced cognitive processes involve controlled processing, decision making, and keeping the decision in memory until it is time to respond, plus the associated motor preparation for pushing the button. Thus, the actual comprehension processes of spoken mini-dialogues will be confounded with decision related processing (see Magne et al., 2005, for similar reasoning).

If the application of a superfluous pitch accent on a referring expression should be seen as a form of marked delivery, giving rise to Nref effects, rather than N400 effects, this should hold for accented nouns (see Dimitrova et al., 2012, for an overview) as well as for accented names and pronouns. The experiment by Taylor et al. (in prep.; Tayor, 2013) that we discussed in the section on reference included conditions where the critical pronoun was accented.

A: “Lisa won the chess tournament”

B: “Oh?”

A: “The teacher congratulated HER.”

Taylor et al. found that accenting the pronoun in this case, as compared to the condition where the pronoun was unaccented, led to a prolonged negativity with a frontal maximum (especially on the right). This is very likely also an Nref effect, indicating the increased effort expended to find the correct referent. So in general it seems that a mismatch between the expected and actual information structure leads to increases in P600 amplitude; in addition, superfluous marking gives rise to an increase in Nref amplitude.

An example of an information structural mismatch that does not involve marked delivery is a study by Hoeks, Brouwer, Hendriks, & Stowe (subm.). They have recently looked at violations of projected information structure in question-answer pairs.

Q1: What happened?
A: The producer fired the actor.

Q2: What did the producer and the director do?
#A: The producer fired the actor.

In the context of question 1, answer A is perfectly fine. However, question 2 sets up an expectation of both the producer and the director to become topics in the answer, either together (e.g., "They went shopping"), or separately, as contrastive topics ("The producer fired the actor, and the director hired him again"). This expectation of contrastive topics is not met by the answer. At 'actor', Hoeks et al. found a positivity that started quite early (350 ms post-onset), had a broad distribution, and became more frontal as time elapsed (from 600 ms onwards). Despite this early onset, they interpreted this posivitity as a P600 due to MRC reorganisation in order to create a coherent representation, for instance including the computation of the pragmatic implication that the director did not do anything because he was powerless or uninterested. This latter kind of processing, or *inference* is the third source of coherence in the mental representation of what is communicated.

3.2.3. Establishing Coherence—Inference

Speakers strive to deliver a coherent message, and listeners to create a coherent representation from the input they get. The links between referring expressions and their antecedents provide a scaffolding for putting into place the new information that is conveyed by an utterance. Cues in the input that indicate where to find topic and focus are extremely helpful in that process. All the holes that are left in the representation are then filled by inferencing, to get at what the speaker might have wanted to say. A specific type of inference only occurs in conversational settings, and are called *conversational implicatures* (Grice, 1975). These arise, for instance, when an answer does not match the requirements of the question regarding relevance (i.e., the answer should be relevant), quantity (i.e., the answer should contain just enough information, not more, not less), quality (i.e., the answer should be truthful) and manner (i.e., the answer should be clear and orderly) (see also Sperber & Wilson, 1986, 1995, who propose that 'relevance' is the overarching concept). The listener will use inferencing to solve the problems that result from a mismatch, including the computation of the real implicature, or: "What did the speaker mean to communicate by creating this mismatch in the first place?". The study by Hoeks et al. (under review) that was mentioned in the previous section can be considered an example of an exchange where a conversational implicature could have been computed. In the mismatch condition, the answer violated the quantity requirements, possibly giving rise to inferencing about its true meaning.

Another type of conversational implicature can be seen in *ironic* utterances. Regel, Gunter, & Friederici (2011) looked at short texts presenting a mismatch between what the protagonist said, and what he believed was actually true (i.e., a mismatch regarding quality requirements). They presented participants with story fragments, for example, about someone hearing many mistakes in the performance of a Bach sonata. The person in question would then look at the orchestra playing the sonata, and say to his or her conversational partner: `These artists are gifted'. In the control condition the person would be listening in ecstasy and again say `These artists are gifted', but this time being sincere. Regel et al. found that in the irony condition the critical verb produced a P600-effect relative to the control condition. This increase in P600 amplitude reflects that the hearer has to compute the ironic meaning to make his interpretation become meaningful. That is, in the irony condition, where the sonata is played with a lot of mistakes, the literal interpretation of the sentence “These artists are gifted” is at odds with the situation, and does therefore not lead to an overall coherent and meaningful interpretation of the speaker's utterance.

These two types of inference can be categorized under the *particularized* conversational implicatures, because they critically depend on the specific context they occur in. The other category is the one of *generalized* conversational implicatures that are more independent of specific aspects of the situation. One prime example of this second category is the so-called 'scalar implicature'. This term refers to the speaker’s *scaling* of an utterance by using a weaker, less informative term on a scale (e.g., ‘some’) instead of a stronger, more informative one (e.g., ‘all’), to communicate that none of the stronger, more informative quantifications on that scale hold. It is not always clear what exactly speakers would like to communicate by using scalar implicatures. For instance, one can say “Some students are hardworking”, to mean that not all students are hardworking. However, it would have been just as easy to use the utterance: "Not all students are hardworking". Maybe the use of scalar implicatures is related to the use of irony, where the speaker perhaps says things he does not believe himself to draw attention to his opinion.

Certain types of scalar implicatures induce world knowledge violations, as in “Some people have lungs” (Nieuwland, Ditman, & Kuperberg, 2010), or “Some turtles have shells” (Noveck & Posada, 2003), as it can be assumed that all people have lungs, and all turtles have shells. Under the Retrieval-Integration account, both the calculation of a scalar implicature and the possibly resulting contextual or world knowledge violations should lead to reorganization of the MRC, and thus cause an increase in P600 amplitude. However, neither of the two studies mentioned above reported any statistics for the P600 window, so we cannot evaluate the MRC hypothesis on the basis of these results. In addition, Nieuwland et al. (2010) and Noveck & Posada (2003) found contradictory results regarding N400 amplitude, but as their materials were not matched on Cloze probability (either within or between experiments), these findings may not be very informative.

A recent study using sentence-picture verification did report analyses in the P600 time window (Hunt, Politzer-Ahles, Gibson, Minai, & Fiorentino, 2012). Hunt et al. used sentences such as “The student has cut some of the brownies” accompanied by pictures where a) none of the brownies had been cut (false), b) all of the brownies had been cut (underinformative), or c) some of the brownies had been cut. They found a P600 for both false and underinformative conditions relative to the true condition, just as predicted by the MRC hypothesis. In addition, they found modulation of the N400, which matched the cloze probabilities for the different sentence-picture pairings (e.g., when hearing “the student sliced some of the …”, a picture where some brownies are sliced will pre-activate ‘brownies’, a picture without any sliced brownie will not, and a picture where all brownies are sliced will be somewhere in between).

A final category of inferences are the well-known *bridging inferences*. Bridging inferences are said to occur when information from the current sentence has to be integrated with the previous context, as in "Horace got some picnic supplies out of the car. The beer was warm." (Clark & Haviland, 1977). Here, readers must infer that beer was included in the picnic supplies, otherwise they would not be able to understand the meaning of the two sentences. In terms of ERP effects, we would predict that the NP 'the beer' would evoke an increased Nref, as 'the beer' is a definite expression which does not yet have an antecedent, also, an N400 will be evoked, as semantic features of beer must be activated, and in addition, a P600 will ensue, both as a consequence of the introduction of a new discourse entity, and as a reflection of the inference processes that eventually lead to the assumption of beer being part of the picnic supplies. To our knowledge this specific kind of bridging inference has not yet been investigated with ERPs, but there is a related experiment by Burkhardt (2007) that may be pertinent to this question. Burkhardt looked at mini-discourses such as

> Yesterday a Ph.D. student was { shot / killed / found dead } downtown.
> The press reported that <u>the pistol</u> …

By using the verb 'shot' in the preceding context sentence, the definite NP 'the pistol' is not a completely new discourse entity, because it has already been implied as an instrument of shot. The formulation 'found dead' by contrast, does not provide any such introduction, as it does not imply an action, or an instrument for that action, so it must be inferred that the pistol had something to do with the student’s death. The verb 'killed' seems to be somewhere in between, as it indicates that the student was murdered, but doesn’t reveal the precise instrument. The P600 effects that were found are consistent with this interpretation: A P600-effect was found for 'found dead', as well as for ‘killed’, relative to ‘shot’. Burkhardt did not find effects on the N400 or report effects on any other component. This may mean that the search for an antecedent, and the pre-activation of the word ‘pistol’ was more or less the same for the three conditions.

In summary, then, listeners strive at having a coherent representation of what is communicated. All three central ways to achieve coherence: establishing reference, creating information structural links, and inferencing, can be investigated with ERPs. Until now, participant were made – at best - to eavesdrop on small and relatively uninvolving texts or, in a few cases, conversations. The presence of a real speaker may change the relative importance of the three cohesive devices, but also change the processing more radically, as more representations come into play, among which the representation of the speaker: who is he/she, and by extension, what does he/she mean by articulating a given utterance? Some researchers have been sceptic about the importance of the representation of our conversational partners for language use (see, e.g., Barr, this volume; Keysar, 2007). They claim that language use, especially language production, is first and foremost rather egocentric and automatic, and any audience design that people manage to do eventually is effortful, and is the first to go when task demands increase. This may to some extent be true, but it is of course obvious that we do adapt to the person that is before us, because our personal and social goals in each situation differ with the person (or persons) we are encountering: is it our boss, our child, our husband or wife, our colleague, our friend, our neighbour, a stranger at a busstop, etc. Every single person and every encounter will be 'assessed' in terms of your personal and social goals at that time, in relation to what you know about them, ranging from superficially visible or inferable characteristics to memories of shared events. All these example persons stand in different (hierarchical) social relations to us, and also differ in familiarity. What we want from our boss is different from what we want from our children, or our students. And that is also different from what we want from our colleagues when we meet them at the coffee machine. So in what we say, and how we say it, we adapt constantly, though on a lower linguistic level, we may be less proficient in tailoring our contributions, and frequently resort to automatized routines. It is very likely that the same holds for language comprehension: interpretation is guided by what we know about our interlocutors. A nice illustration of that fact is a study by Van Berkum, Van den Brink, Tesink, Kos, & Hagoort (2008). Participants listening to sentences such as “I have a large tattoo on my back” spoken with an upper-class accent, showed an increased N400 amplitude to the critical word ‘tattoo’ as compared to the same sentence uttered in a low-class accent. This finding shows that listeners take the characteristics of the speaker into account, and that they are able to do that very quickly. So we would like to conclude that speakers matter, though perhaps not always on all levels of language use.

3.3. Dynamic Aspects of Communication

When the speaker is present, the language situation changes from static to dynamic. We have to negotiate turns, and the frequency of turns. We have to establish whether it is allowed to interrupt the speaker, or whether we let ourselves be interrupted. We have to give and receive backchannel information, and decide on the sort of feedback, and the timing of it. Kraut et al. (1982) showed that feedback serves to regulate the content of the speech. It also has an effect on more structural aspects, such as the form of referring expressions, the occurrence of ellipsis, etc. But backchannel information also indicates that the listener is interested and committed to engage in the conversation. Furthermore, feedback also reflects the state of the relationship between speaker and listener: smiles and friendly nods signal a positive relation. Unfortunately, there seems to be not a single study on electrophysiology of language that has looked at these aspects of human interaction. The Dialogue Immersion Paradigm may play a role in filling this gap.

4. Discussion and Conclusion

With ERPs we have a valid and reliable toolkit at our disposal to study language use in discourse and conversation. We have identified three components that are linked to three basic linguistic operations: establishing reference, meaning activation and integration: the *Nref* is sensitive to referential processing: searching for the antecedent in the discourse representation or Mental Representation of what is Communicated, MRC. The *N400* is sensitive to pre-activation, and reflects the retrieval of semantic (and lexical) features of incoming stimuli. And the *P600* reflects the construction or revision of an MRC. In the meantime, there are still some problems that need to be solved. For instance, one important problem is how we can design experimental methods that allow us to measure ERPs in active conversation. A first step may be the *Dialogue Immersion Paradigm* (DIP), in which participants are under the illusion that they are talking via an intercom to a person in another room, while the utterances of this person are in fact pre-recorded (Hoeks et al., in prep.). To make this work, the participant's own contributions are also scripted, such that they match the responses of their conversational partner. The DIP provides a means, be it a rather restrictive one, to study the social, pragmatic, and dynamic aspects of communication that come into play when participants are engaged in an actual conversation.

Another issue is a bit more technical. Until now, much research has focused on the N400 and how it can be modulated by the context. In the current chapter, we have argued that the P600 is the most interesting component for the investigation of discourse and dialogue. However, the processes reflected in N400 and P600 amplitude may overlap in time. Because ERPs are *additive*, this means that the amplitude of any P600 depends on the amplitude of the preceding N400. In other words, a specific P600 waveform of a given magnitude will turn out more positive if for any reason the preceding N400 is more positive, and P600 amplitude will turn out less positive if the preceding N400 is less positive. Thus, P600 amplitude is modulated by N400 amplitude, and possible P600-effects may become obfuscated. As a consequence, we may conclude that a given contrast between an experimental and a control condition only produces an N400-effect, and no P600-effect, while in reality there is a difference in P600 activity. This issue has been noted before in the literature (e.g., Hagoort, 2003; Kutas, Van Petten, & Kluender, 2006), but has of yet not led to a any change in how ERPs are analyzed. One reason for this is probably that the P600 has often been seen as an *effect* that is only generated when something goes wrong during processing, and not as a *component* that is always present in the ERP signal. On the other hand, component overlap is in fact the reason that the P600 has been taken to be an effect, because its overlap with the N400 component fosters the impression that it is sometimes present (e.g., no preceding N400-effect or rather large P600-effect) and sometimes absent (e.g., large N400-effect or rather small P600-effect). It is not easy to find a good way to estimate 'true' P600 amplitude that takes into account preceding differences in the ERP signal. One approach to this would be to baseline on the N400 time window (cf. Hagoort, 2003). If we can find a way to adjust for such prior differences between conditions, we might explain why a P600-effect sometimes appears to be absent where it is in fact expected (e.g., see Van Petten & Luka, 2012).

Not only component overlap, but also other differences in the ERP signal preceding the target word are to be reckoned with, especially where utterances appear in a context, as is the typical case in discourse and conversation. Every change in the context may affect the expectations that listeners have about the information contained in the upcoming utterances. In addition, in spoken language, especially when languages are used where information structure is indicated by means of prosody, prosodic cues are sometimes available well in advance of the target word. For instance, prosodic marking of topic and focus is not strictly local, but has an effect on the entire prosodic contour of an utterance. This is also a problem that we need to take seriously, and for we which we do not yet have a satisfactory solution. Further research in this area is definitely necessary.

Addressing these issues is critical for the successful investigation of the internal functional structure of the P600. Brouwer et al. (2012) suggested that the P600 may not reflect one single process, but subsume many different sub-processes, which can be differentiated and labeled on the basis of differences in onset, duration and scalp distribution. In the model proposed by Brouwer and Hoeks (2013), the P600 component is generated in the left Inferior Frontal Gyrus (lIFG; BA 44/45/47). They argued that the complex neuroarchitecture of this area supports a fine-grained functional topology, hosting different sub-processes of MRC construction and reorganization. As such, different P600s in terms of scalp-distribution, and other electrophysiological properties like onset, duration, and amplitude, arise because they are generated in different, but potentially overlapping sub-areas of the lIFG. However, the functional and anatomical neurocognitive organization that underlies the scalp-distribution of an effect, is different for each individual brain. Thus, the derivation of a sound functional categorization of P600 is not as straightforward as it might seem. Possibly, this issue may be circumvented by comparing anatomy and ERP components on an individual, within-participant level, and not (only) by looking at between-participants data.

Once we know more about what the different P600 subtypes mean (and by which brain areas they are subserved), we may start to answer questions regarding the nature of the representations involved in conversation. We have suggested that successful conversation requires an interactant to manage a number of representations: two representations for himself: his private goals and knowledge, and his public 'face', two representations (public and private) of his main conversational partner, a representation of the content or the *upshot* of the conversation as a whole, and a representation of the more situational aspects of the conversational setting. The question is what these representations look like, how they interact, and how they are accessed. Are they all part of a single representation, or are they stored and maintained somewhat separately, perhaps in totally different brain areas? It would make sense to separate private and public representations physically, to prevent leakage, though in the brain, distance doesn't seem to matter too much.

In conclusion, then, if we want to arrive at a plausible, neurocognitive model of communication, we cannot afford to neglect the social, pragmatic and dynamic aspects of language use. The actual or perceived presence of an interactant may crucially shape the representations and the processes involved in communication. Thus, let us turn to investigating active conversation.

Acknowledgements

We would like to thank Noortje Venhuizen for comments on an earlier version of this manuscript. Writing of this chapter was in part supported by the Netherlands Organization for Scientific Research (NWO) PGW grant 10-26.

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