31 A Cognitive Neuroscience Perspective on Language Comprehension in Context

JOS J. A. VAN BERKUM AND MANTE S. NIEUWLAND

1. Beyond the Code

Language is a great tool, an infinitely extendable discrete combinatorial coding system that has amplified the communicative capabilities of *Homo sapiens* far beyond that of other Great Apes or any other species on this planet. The beauty of this system has been documented by linguists in great detail, and, as evidenced by many chapters in this book, we are beginning to unravel how the human brain supports its acquisition and use. But what do we use it *for*? How does using the code mesh with, and amplify, whatever our particular animal species is up to *anyway* in life, as we navigate the physical and social world?

What the human brain shares with that of many other species is a capability to represent the external environment in great detail, such that we know what is around us, and what our options are—vast areas of the human neocortex are map-building areas (Damasio, 2010). What we also share with many other species is a set of affective control systems that make us care about the environment, such that we act on opportunities and threats in appropriate ways, and, if we don't do anything too stupid, learn from it along the way (Panksepp & Biven, 2012). Finally, like all species that can learn, we are forward-looking creatures, extrapolating from the here and now, and from what we have learned in the past, toward how the world might soon be. So, with virtually all of this in place well before language entered the scene, what did language add? And, given that all of those pre-existing capabilities and inclinations are still with us today and control everything we do, what are the implications for real-time language processing? In this chapter, we review some of our cognitive neuroscience research on how language comprehension unfolds in the context of our map-making, affective, and forward-looking nature.

The most obvious bonus of language is its referential power, the fact that it allows speakers to draw other people's attention to very precisely delineated aspects of the world, as such enriching their mental map of the here and now, as well as of possible, past, or future states of affairs, in infinitely detailed ways. Language helps us to convey that berries can be found in some particular spot down this and that track, but only in late summer, and that if we coordinate our attack well and come up from behind, the elephant on the left is probably our best target. And, as evidenced by examples like *I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth*, language also allows us to draw other people's attention to our own mental representations. Because understanding reference is so central to the amplifying power of language, we start our review by examining how addressees (or overhearers) infer the speaker's referential intention, that is, relate apparently simple referential expressions such as *he*, *this nation*, or *itself* to elements of their mental representation of the real or imaginary environment.

Mapping what people refer to, and what they want to achieve by doing so, is only half of the story, though. What matters in the end is how all that relates to what addressees and overhearers *care about*. As argued extensively elsewhere (van Berkum, 2018, 2019a), language users are not dispassionate code-cracking and inference-generating information processors. We usually *care* about what people refer to and what their social intentions are. And, just like in other domains of mental life, it is these *affective* (emotional, evaluative) responses that typically move us (Damasio, 2010; Panksepp & Biven, 2012). That is, much of what makes language do real work, in other words, generate "perlocutionary effects" out there in the world, is how people feel about it, and what they think or do as a result. In the second part of this review, we discuss some of our cognitive neuroscience work on how the unfolding linguistic code makes contact with what people care about, and we introduce a model for thinking about the processes involved.

Understanding language comprehension in context requires an analysis of how the unfolding linguistic code rapidly makes contact with representations of the referential context, and of how the code can in the end affectively move comprehenders. However, language comprehension is not just about how we *react* to bits of code. Our vast capacity to learn about the world, and about how we communicate about that world, also allows us to *anticipate* upcoming communication (van Berkum, 2013). In the third part of our review, we briefly discuss some of our research on such anticipation.

2. *The Referential Context for Language*

The fact that language is about the world and refers to the world is what makes language so incredibly useful. The referential link between language and the world is perhaps the single most discussed issue throughout the philosophy of language (Martinich, 1985; Recanati, 1993). In contemporary cognitive science and psycholinguistics, the understanding of referential expressions, or *reference resolution*, also takes center stage by virtue of its importance in language acquisition and in the computation of speaker meaning (e.g., Gibson & Pearlmutter, 2011; Trueswell & Tanenhaus, 2005). The need to understand reference develops as early as language development itself, when children learn the meaning of words through understanding the referential intention of a speaker (Bloom, 2000; Tomasello, 2009). Already at a very young age (one to two years), children are sensitive to cues about referential intent such as the speaker's gaze, pointing, and prosody, and they use these cues to constrain the meaning of novel or ambiguous words (Bloom, 2000). And as early as age five, children can take into account the private perspective of a speaker when interpreting the speaker's referential expressions (Nadig & Sedivy, 2002), demonstrating a highly complex cognitive skill associated with Theory of Mind (Frith & Frith, 2005). Perhaps unsurprisingly, then, adults typically resolve reference without any conscious effort, whether reference is made to a nonlinguistic context (e.g., an object in the physical surroundings or real-world knowledge) or to a linguistic context (e.g., something that was mentioned before). This section zooms in on the latter, *anaphoric reference* to a linguistic antecedent.

2.1. Understanding Anaphoric Reference Anaphoric reference is one of the pillars of discourse cohesion (Sanford & Garrod, 1989), the stuff that makes sentences part of the same discourse. Referring to a previously mentioned concept is also the most basic way to stay on topic during conversation. How do people understand anaphora? In psychological theories of anaphora comprehension, comprehenders reactivate the intended antecedent from their memory representation of the discourse and subsequently integrate this antecedent information into the overall representation of the narrated event (e.g., Gernsbacher, 1989; Gerrig & McKoon, 1998; Myers & O'Brien, 1998; Sanford & Garrod, 1989). Antecedent reactivation is thus considered to be a memory-based process, in which the anaphor serves as a memory cue to reactivate or access the antecedent (e.g., Lewis & Vasishth, 2005; see also Martin, 2016). It follows that ease of anaphor resolution depends on the extent to which the antecedent is already activated before the anaphor appears and on how strongly the intended antecedent is uniquely cued by the semantic and syntactic content of the anaphor. Antecedents that are in the current focus of the discourse, and therefore relatively activated, are easier to access than those that are not. Focused antecedents can then be referred to with reduced-form anaphora like pronouns (e.g., *The construction worker smiled when he got his paycheck*). Pronouns may be very efficient referential devices, but their shallow content makes them particularly prone to ambiguity in interpretation (e.g., *The construction worker smiled at the foreman when he got his paycheck*, where *he* could refer to either worker). Referential ambiguity or misinterpretation may be a specific case where regular interpretation hampers, but this situation is not uncommon in everyday language interactions. Temporary ambiguity as in *That lady with the blue hat*, referring to one lady among other ladies (and thus disambiguated at *blue*), is particularly common. Temporary ambiguity simply arises because speakers do not always avoid ambiguity by mentioning the disambiguating information first (e.g., *that blue-hatted lady*). Having to briefly deal with ambiguity may just be that price to pay, at least occasionally, for having a referential communication system that works quickly as well as very flexibly.

Fortunately for language researchers, referential ambiguity offers a useful paradigm to investigate the time course and neural machinery associated with anaphor comprehension (for a review, see Nieuwland & van Berkum, 2008b; van Berkum, Koornneef, Otten & Nieuwland, 2007). This typically involves a comparison of behavioral or brain responses to referentially ambiguous expressions with those to nonambiguous expressions. One prominent example is the effect of referential ambiguity on people's looking patterns. This can be demonstrated with the *visual world paradigm* (see Trueswell & Tanenhaus, 2005), where participants look at objects in a display while receiving spoken instructions to touch or move those objects. Studies with this paradigm show that participants evenly distribute their fixations across potential referents for ambiguous expressions or quickly fixate on a single referent for nonambiguous expressions, all within 200 to 300 ms after the acoustic onset of a referential expression. A similar effect onset of referential ambiguity is observed in event-related brain potentials as measured by electroencephalography (EEG) recordings during language comprehension. Compared to nonambiguous anaphors, ambiguous anaphors elicit a sustained, negative voltage deflection with a frontocentral maximum that starts at about 200 to 300 ms after anaphor onset, called the *Nref effect* (van Berkum et al., 2007). Findings from a series of experiments suggest that this effect indexes a cognitively effortful attempt to deal with a referential problem and to establish a referentially coherent interpretation. The Nref effect has been observed for written and spoken noun phrase anaphora such as *girl* in a story context that contains two girls (van Berkum, Brown, & Hagoort, 1999; van Berkum, Brown, Hagoort, & Zwitserlood, 2003), for written and spoken pronouns such as *he* in a sentence context with two male characters (Nieuwland & van Berkum, 2006a; van Berkum, Zwitserlood, Bastiaansen, Brown, & Hagoort, 2004), as well as for elliptical expressions such as *another* (Martin, Nieuwland & Carreiras, 2012, 2014). The Nref effect appears when the context contains two equally plausible antecedents for an anaphor (Nieuwland, Otten & van Berkum, 2007; Nieuwland & van Berkum, 2006a) or when an anaphoric pronoun refers to an unknown referent (Nieuwland, 2014; see figure 31.1, left graph). The Nref effect is not elicited when only one of two antecedents is a plausible referent, in which case there is no genuine ambiguity, or when the anaphoric noun phrase itself is a semantically anomalous sentence continuation (Nieuwland & van Berkum, 2008a).

These observations demonstrate some key aspects of anaphor comprehension. The Nref effect onset, the time point at which event-related potentials (ERPs) elicited by ambiguous and nonambiguous words first start to diverge, shows that anaphor comprehension is rapidly impacted by the presence of suitable antecedents in the context, well before the onset of the subsequent word. Moreover, the spoken language results suggest that this effect of referential context starts off well before the complete anaphor has been heard (van Berkum, Brown, & Hagoort, 1999; Nieuwland, Otten, & van Berkum, 2007), after having heard perhaps only one or two phonemes. This shows anaphor comprehension to be a highly incremental process, meaning that people use relevant information as quickly and efficiently as possible to establish the intended referent. In terms of time course, this puts anaphor comprehension on a par with other influences on the computation of speaker meaning (van Berkum, 2009, 2012), such as whether an expression is plausible with respect to what was said before (van Berkum, van den Brink, Tesink, Kos, & Hagoort, 2008), who said it (van Berkum, Zwitserlood, et al., 2003), or knowledge about the world (Hagoort, Hald, Bastiaansen, & Petersson, 2004).

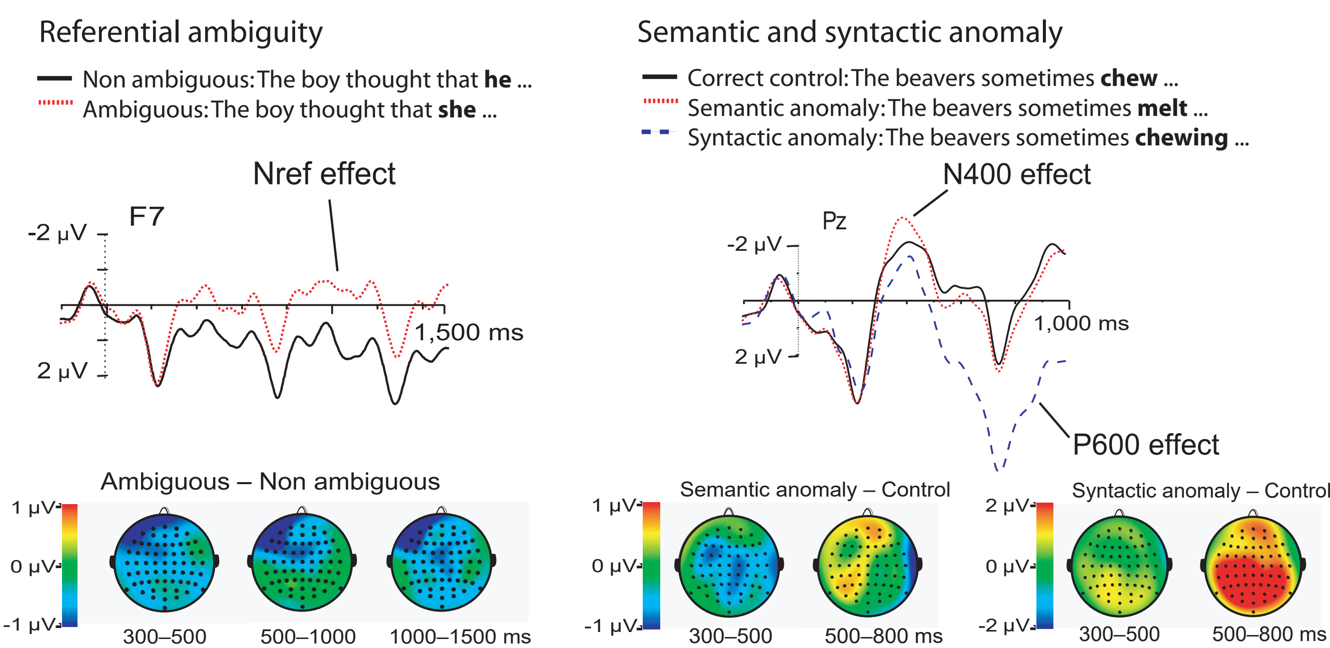

FIGURE 31.1 ERP effects of referential ambiguity for pronouns (*left graphs*, channel F7), and of semantic anomaly and syntactic anomaly (*right graphs*, channel Pz). This figure is adapted from Nieuwland (2014).

Irrespective of its time course, the Nref effect morphology and scalp distribution suggests that referential ambiguity entails processing costs that are qualitatively distinct from those imposed by semantically or syntactically problematic words (see figure 31.1, right graph), which elicit N400 and P600 effects, respectively. Referential ambiguity, unlike semantic ambiguity, does not impact the retrieval of lexical-semantic information associated with the anaphor, as arguably would be reflected in N400 ERP modulation (Nieuwland & van Berkum, 2008a). Building on memory-based accounts of language comprehension, referential ambiguity can be construed as a case of memory retrieval interference from overlapping content (e.g., Lewis & Vasishth, 2005). The observed ERP effects only point toward a qualitative distinction between Nref effect activity and N400/P600 activity, which is consistent with different sets of neural generators as has been revealed through functional MRI (fMRI) (Nieuwland, Petersson, & van Berkum, 2007).

Thus far, this section has focused strongly on referential ambiguity and on what its processing consequences may say about anaphor comprehension. But nonambiguous, *unproblematic* anaphor comprehension is arguably the default situation in natural language use. In the next section, we discuss a proposal for how this may work in the brain.

2.2. A Nascent Corticohippocampal Theory of Reference While the neurobiology of language has made major advances in recent years (Hickok & Small, 2015), it is still relatively unknown how the brain achieves the important feat of reference. Extant neurobiological accounts of sentence-level language comprehension primarily focus on syntactic and semantic processing in the traditional temporal-frontal language network (e.g., Friederici, 2012; Hagoort & Indefrey, 2014). Such accounts localize syntactic and semantic combinatorial operations in left prefrontal cortex (cf. Bemis & Pylkkänen, 2011), which use syntactic and lexical-semantic representations that are stored in temporal cortex and the angular gyrus (parietal cortex). To date, these accounts have had very little to say about reference.

As a first step toward a fully articulated neurobiological theory of language that captures reference, Nieuwland and Martin (2017) recently proposed a corticohippocampal theory of reference. This coarse-grained theory bridges psycholinguistic theories of reference with the neurobiology of recognition memory and of language. It builds on the broad consensus about antecedent reactivation based on the content features of the anaphor (e.g., Myers & O'Brien, 1998; Sanford & Garrod, 1989), such that a referential link can be established between multiple instantiations of the same concept despite linguistic form differences. The antecedent reactivation process equates to, or, minimally, involves recognition memory function, which allows people to distinguish new and old information. In recognition memory research, successful retrieval (i.e., recognition) is associated with increased activity in and connectivity between the medial temporal lobe and posterior parietal cortex (Aggleton & Brown, 2006; Eichenbaum, Yonelinas, & Ranganath, 2007; Wagner, Shannon, Kahn, & Buckner, 2005), which reflects the reinstatement of previously encoded items (e.g., Rissman & Wagner, 2012; Staresina, Henson, Kriegeskorte, & Alink, 2012). Building on these findings, the core claim of the corticohippocampal theory of reference is that anaphor comprehension draws on the interaction between the brain's recognition memory network (medial temporal lobe, including the hippocampus, and posterior parietal cortex) and the canonical frontal-temporal language network, with the former being chiefly responsible for antecedent reactivation and the latter primarily responsible for bringing the unfolding sentence representation to bear on situation model construction.

Available support for the corticohippocampal theory of reference comes from neuropsychological studies and neuroimaging. Hippocampal amnesia patients, who suffer from episodic memory dysfunction due to a hippocampal lesion, show impairments in pronoun comprehension (Kurczek, Brown-Schmidt, & Duff, 2013) and sometimes produce indefinite reference when definite reference is more appropriate (e.g., *a camel* where one would use *the camel* to refer to a camel that had been discussed before; Duff, Gupta, Hengst, Tranel, & Cohen, 2011). The hippocampus also shows increased blood oxygenation level–dependent fMRI activity for pronouns that match a given, "old" antecedent in the sentence context compared to pronouns that refer to an unknown, "new" antecedent (Nieuwland, Petersson, & van Berkum, 2007; see figure 31.2, left graph). This comparison is also associated with increased gamma-band neural oscillatory power, as measured in EEG activity (Nieuwland & Martin, 2017; van Berkum et al., 2004; see figure 31.2, right graph). Nieuwland and Martin showed that these increases in power take place in posterior parietal cortex at ~400 to 600 ms after pronoun onset and in the frontal-temporal cortex at ~500 to 1000 ms after pronoun onset, suggesting the involvement of the brain's parietal recognition memory network[1] and the canonical language network in successful reference resolution.

Several important predictions from the corticohippocampal theory of reference remain to be tested. For

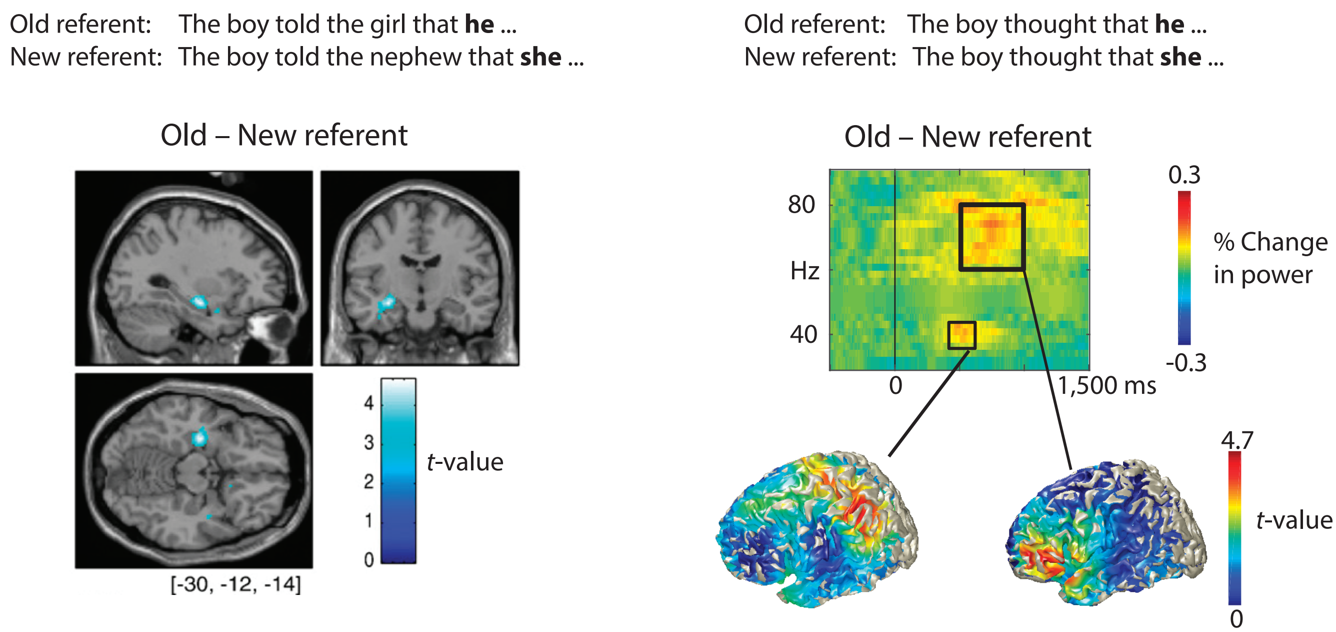

FIGURE 31.2 Relative increase in hippocampal blood oxygenation level–dependent fMRI activity for old referents compared to new referents (*left graph*, adapted from Nieuwland, Petersson, & van Berkum, 2007). Stronger gamma-band oscillatory EEG activity (measured as relative change in power) for old referents compared to new referents (*right graph*, adapted from Nieuwland & Martin, 2017). An increase at ~40 Hz at ~400 to 600 ms after pronoun onset was localized to left posterior parietal cortex, and an increase at ~60 to 80 Hz at ~500 to 1000 ms after pronoun onset was localized to left inferior frontal cortex.

example, successful reference resolution should lead to increased connectivity between the recognition memory network and language network, but activity in the recognition memory network may be of shorter duration or may even take place before activity in the language network, reflecting the processing phases of antecedent reactivation and sentence-level integration (e.g., Sanford & Garrod, 1989). In addition, the respective contributions of the hippocampus and posterior parietal cortex to antecedent reactivation need to be determined. Perhaps the initial binding operations between anaphor and antecedent take place in the hippocampus (e.g., Duff & Brown-Schmidt, 2012), but full reactivation, by bringing antecedent information back into the focus of attention, takes place in posterior parietal cortex (Wagner et al., 2005).

The corticohippocampal theory of reference could be a step in the right direction, but it only really covers anaphoric reference. Other aspects of reference are equally important in order to understand how the brain deals with language in context. Another common form of reference, nonanaphoric reference to things that are perceptually available, presumably does not engage recognition memory, but, instead may require multimodal integration of information from linguistic and perceptual modalities (e.g., Brodbeck, Gwilliams, & Pylkkänen, 2016; Willems, Özyürek, & Hagoort, 2008; see Martin, 2016, for a sensory integration-based process model). Moreover, neuroimaging research is only just starting to reveal the neurocognitive mechanisms for comprehension of reference to hypothetical worlds as opposed to real-life events (e.g., Menenti, Petersson, Scheeringa, & Hagoort, 2009; Nieuwland, 2012). For a full understanding of the various linguistic phenomena that are considered to be *referential* by nature, there are more than enough challenges ahead.

3. The Affective Context for Language

As we have seen, language greatly amplifies the mapmaking capabilities of our species, via arbitrarily precise reference to the world out there, and, as part of that world, our beliefs or imaginations about what is, was, or might be. As revealed by careful analyses in pragmatics (Tomasello, 2008; Clark, 1996), however, drawing attention to a particular referent or state of affairs is often just the beginning: communicators use language to inform, but also to move people around or share feelings. Saying things like *I forgot to buy cat food* to one's spouse upon returning home from the supermarket might be intended as a purely informative and helpful reference to some state of affairs in the world, but the speaker's intention in such cases is usually to share frustration and/or to elegantly get somebody else in the household to go back and buy a few cans. Language is used in the context of social intentions, as a means of achieving those intentions.

In a way, inferring the social intentions behind an utterance like *I forgot to buy cat food* is just another instance of mapping the world: depending on context, the listener not only learns about the speaker's shopping intention, its incomplete realization, and the implied current shortage of cat food, but, via additional inferences, also that the speaker would like the addressee to go to the store and buy some. However, whether all this additional information will have any effect on the listener beyond enriching his mental map of the world with somebody else's referential and social intentions depends on something else. Research on emotion and associated phenomena (evaluations, preferences, moods) has revealed that map making only takes us that far, and that in order to be moved, what is relevant is how the result *relates to our interests* (Damasio, 2010; Frijda, 2008; Lazarus, 1991; Panksepp & Biven, 2012; Scherer, 2005; Zajonc, 1980; see van Berkum, 2018, 2019a, 2019b, for language-relevant reviews). Emotions, evaluations, preferences and moods are *motive states*, urging or nudging us to act on entities or events out there in the world in certain ways, all because of how those entities or events *relate to our interests*. For example, because I care for my cat, the speaker's indirect reference to the cat food shortage may well by itself prompt me to go to the store, and if not, the fact that I care about my spouse's desires, or about being a cooperative partner, may well send me there anyway. I need not be conscious of such interests, nor of the emotional responses and associated motive states they induce. But without them, an utterance like *I forgot to buy cat food* would most likely leave me inert.

3.1. Understanding Affective Language People care about lots of things and they can talk about all of it. At the referential level, therefore, the possibilities for language that is affectively relevant are already infinite. However, because we are a highly social species, much of what we in fact care about is about how conspecifics relate to us and others, what they did or did not do, and whether they did the right thing (Greene, 2014). The interests at stake here are high. For a species heavily invested in cooperation, for example, being respected is critical: our public face (Goffman, 1959) determines whether people will trust and select us for collaboration, and, as in other primate species, respect also guarantees a comfortable position in social hierarchies, with access to resources.

These interests make for a context in which a canonically emotion-relevant piece of language, the verbal insult, can hit hard, to such an extent that we can see traces of this even in laboratory studies. In a recent EEG study, for example, Otten, Mann, van Berkum, and Jonas (2016) had people read insults such as "You are such a loser" or "Your opinions are too ridiculous for words." Compared to verbal compliment controls such as "You are so nice" or "Your opinion is often very interesting and illuminating," critical words in verbal insults elicited a Late Positive Potential (LPP) effect between 600 and 900 ms, a globally distributed positivity that is typically observed with emotional stimuli, and that is believed to index emotion-induced enhanced processing (Cacioppo, Crites, Berntson, & Coles, 1993; Sabatinelli, Keil, Frank, & Lang, 2013; see Hajcak, MacNamara, & Olvet, 2010, for review). Insulting words also elicited a negativity at ~300 to 400 ms, which, if interpreted as an N400 effect,[2] suggests that the insult was at some level unexpected and as such interfered with context-sensitive lexical retrieval (Kutas & Federmeier, 2011; van Berkum, 2009). Interestingly, when the insulting language was accompanied with cues to *public* humiliation (including recorded laughter and the outline of a crowd), the insult-induced LPP effect became considerably stronger and emerged much earlier, at some 300 ms, whereas the insult-induced negativity disappeared. We take this increase in the LPP to reflect that, because of their connection to public face and one's social hierarchy position, insults are usually much more threatening when delivered publically. In line with other observations (e.g., van Berkum, Holleman, Nieuwland, Otten, & Murre, 2009) of potential N400-LPP overlap, an increased LPP effect due to cues to public humiliation may perhaps have eliminated the N400-like negativity at ~300 to 400 ms.

In another recent EEG study (Struiksma, De Mulder, & van Berkum, 2019), we used a repetition design to explore whether people adapt to insults, and if so, in what way. Participants were exposed to massively repeated verbal insults such as "___ is a bitch" or "___ is ugly," presented in blocks that were mixed with blocks of linguistically matched compliments, like "___ is a sweetheart" or "___ is beautiful." Relative to compliments, insulting words elicited the same two effects as observed by Otten et al. (2016): an LPP effect, preceded by an enhanced N400-like negativity. In addition, however, insulting words elicited a very early modulation of the P2, indicative of enhanced attention. In contrast to the LPP and N400-like effects, the P2 effect was extremely robust to repetition, and also emerged when the participant's name was replaced by that of another person. Interestingly, post hoc analyses revealed that these effects hinged on those insults in the item set that had used a taboo word (e.g., *bitch*, but not, e.g., *ugly*). Because insults with taboo words were randomly intermixed with other insults, this also reveals that the ERP responses observed are not due to block-based anticipation. We suspect that what is happening here is that such swearwords very rapidly signal a taboo transgression, possibly as soon as they are retrieved from long-term memory, and that this is the source of the very rapid and "victim-insensitive" P2 effect.

This brings us to another domain where the interests guarded by emotion are high: morality. There is growing awareness that our species is (at least partly) moral by nature rather than "by culture," with morality and the associated emotions considered as biological adaptations that foster within-group collaboration and between-group competition (Greene, 2014; Haidt, 2012). If, as the relevant accounts hold, our perception of conspecifics (and ourselves) is intrinsically moral, language that touches on morality should have very rapid effects in processing (much like other forms of "moral perception"; Gantman & van Bavel, 2015). The early taboo-conditioned effects reported by Struiksma et al. (2019) are compatible with this: the use of an interpersonally violent taboo word seems to attract attention much like a slap in the face would do (Irvine, 2013), in a robust way that does not adapt with repetition, and is also very salient if *somebody else* is the victim.

Research on other types of morally loaded language also reveal a strong and rapid sensitivity to morally objectionable language. In one EEG study (van Berkum et al., 2009), participants with radically different (strict Christian or non-Christian) moral backgrounds read attitude survey statements that did or did not clash with their value system, such as "I think abortion is an acceptable/unacceptable course of action." Relative to value-consistent words, words that rendered the unfolding statement morally objectionable for the participant at hand (e.g., in the preceding example, "acceptable" for a strict Christian) elicited an early positivity at ~200 to 250 ms, a small centroparietally distributed N400 effect peaking at 400 ms, and an increased LPP between 500 and 650 ms, with the offending word defined by the specific moral background (see figure 31.3). Although they do not always occur together in the same study, each of these three morally induced EEG effects has been replicated, partly by other labs, and in one case also outside of the attitude survey context (Hundrieser & Stahl, 2016; Leuthold, Kunkel, Mackenzie, & Filik, 2015; Struiksma, Pantazi, de Mulder, & van Berkum, 2013).

Furthermore, we literally frown on language that describes morally objectionable behavior. In recent work ('t Hart, Struiksma, van Boxtel, & van Berkum, 2018; 2019), we have turned to facial electromyography to assess subtle—and not necessarily visible—activity of the frowning muscle (corrugator supercilli), as an index of language-induced moral indignation. In two studies, participants read short narratives where protagonists behaved in morally objectionable or prosocial ways (e.g., deliberately accelerating one's car through a

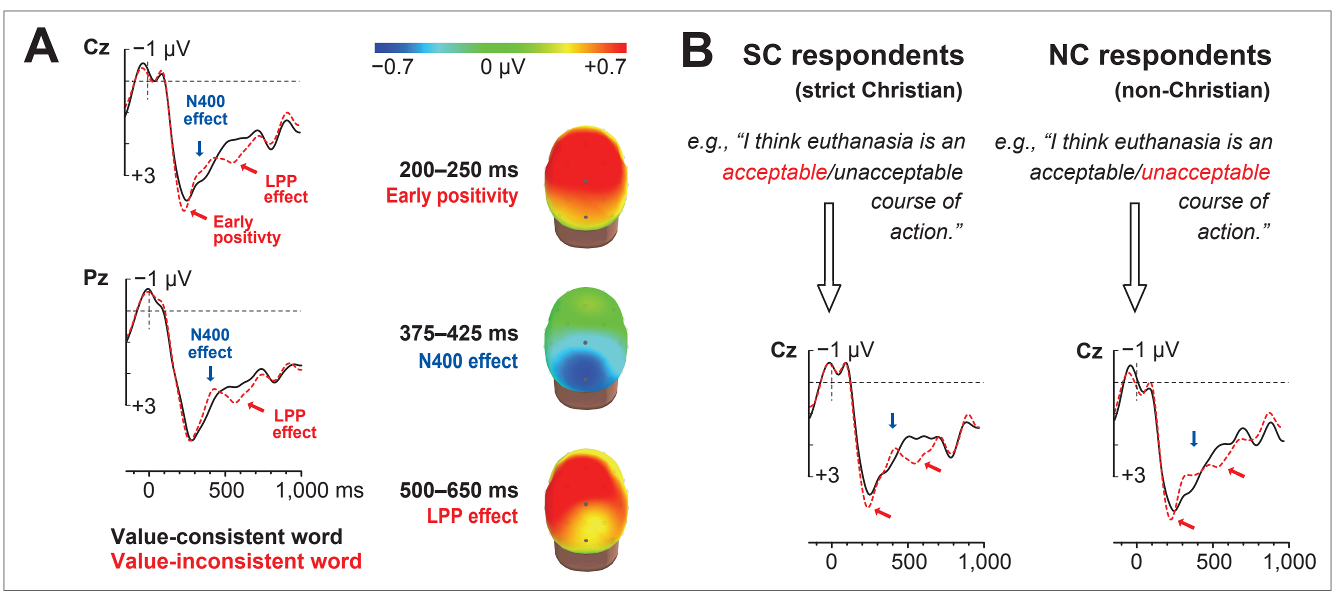

FIGURE 31.3 Triphasic response to morally objectionable language. (A) ERPs to value-consistent and value-inconsistent critical words, pooled across two groups of respondents, with scalp distributions for three differential effects. (B) ERPs and example item for two groups separately. Value-inconsistency is rapidly detected (early positivity), is conceptually unexpected (N400 effect), and induces additional processing (LPP effect). Scalp distributions are rendered on a three-dimensional head model (with Cz and Pz marked). See van Berkum et al. (2009) for details.

puddle to soak a pedestrian or deliberately slowing down instead). Relative to descriptions of prosocial behavior, descriptions of morally *objectionable* behavior induced a strong activation of the corrugator, which began to emerge at about 1 s into the offending passage. Furthermore, good or bad events that subsequently befell these protagonists also induced rapid differential corrugator responses, in ways that are again compatible with rapid moral (in this case fairness-based) evaluation.

In all, our findings indicate that as soon as unfolding language relates to strong interests of ours as affective creatures with things at stake, clear processing consequences emerge, in EEG as well as facial electromyography. As already mentioned, we believe that these effects at least partly reflect the response of our affective systems, whose job it is to watch over our interests and evaluate the environment accordingly. Those systems, and the interests they serve, provide the context for any bit of language coming in.

3.2. A Model for Affective Language Comprehension The findings discussed merely sample the neurocognitive exploration of how language moves people. For example, there is neurocognitive research on emotional prosody (e.g., Heilman, Bowers, Speedie, & Coslett, 1984; Pell, 1999), on the processing of face-saving indirectness and irony (e.g., Bašnákova, van Berkum, Weber, & Hagoort, 2015; Bašnákova, Weber, Petersson, van Berkum, & Hagoort, 2014; Spotorno, Koun, Prado, van der Henst, & Noveck, 2012), and on the impact of strongly valenced words and phrases (e.g., Citron, 2012; Fischler & Bradley, 2006; Foroni & Semin, 2009; Holt, Lynn, & Kuperberg, 2009; Wang & Bastiaansen, 2014). What has been missing, though, is a general perspective on how to conceive of these various effects—in line with general biases in the language sciences, extant models of language processing are fiercely nonaffective.

The *Affective Language Comprehension* (ALC) model (van Berkum, 2018, 2019a) depicted in figure 31.4 is a first attempt to remedy this, in a way that goes beyond the crude idea of "emotion words" and that respects the complexity of language. Building on sentence-oriented as well as more generic sentence-oriented and gesture-oriented analyses of human communication (e.g., Jackendoff, 2007; Tomasello, 2008), the model combines standard psycholinguistic and experimental pragmatic conceptions of what is needed to understand language with knowledge of how emotion can be triggered, consciously or unconsciously. The result is an explicit framework of processes and the associated representations, ranging from lexical retrieval and phrase-level linguistic processing to recovering the speaker's stance, referential intention, and social intention, plus whatever else the speaker did not intend but can be inferred anyway. Importantly, the ALC model predicts that an utterance can generate emotional responses in the addressee (or, for that matter, an overhearer) at *all levels of analysis*, from the ultimately relevant construal of the speaker's social intention all the way "down" to the level where a sign's meaning is retrieved from the mental lexicon. As such, the ALC model provides us with a detailed map of where and how the "perlocutionary effects" of an utterance arise, and a context within which we can also discuss how various phenomena involving rhetoric and persuasion (e.g., framing) might come about, as language is processed in real time. Along the way, the model provides a principled account of different forms of *word valence* (see van Berkum, 2018).

To give just one example related to the Struiksma et al. (2019) study, consider the potential emotional impact of hearing *you are a bitch/asshole!* uttered toward you in a way that is clearly aggressive. At the level of the social move, the speaker overtly expresses contempt for you, a clear trigger for emotion. However, beyond this obvious observation, the ALC model makes explicit various other potentially evocative ingredients that emerge in the language processing stream. One is the speaker's *referential* intention: although the situation described by the speaker (you being a bitch or asshole) need not be a correct characterization of the state of affairs in the world, *imagining* this state as an unavoidable part of language processing may nevertheless *still* induce an affective response (this is presumably part of why "benign," "playful" insults can still sting). Another additional ingredient involves experience-based emotional connotations of particular words or other signs. If a word like *bitch* has often been used to implement aggressive social moves or to describe very negative situations, or has often been witnessed to elicit strong negative responses in others, simple "Pavlovian" conditioning will lay down negative affective connotations as part of the memory trace for that particular word. As with other emotionally conditioned stimuli (e.g., a light that sufficiently reliably predicts a shock), the *mere use of the word* can then evoke a rapid automatic affective response, independent of the precise sentence-level message, the stance, the referential, and the social intention of the speaker.

4. Context-Dependent Anticipation

We have reviewed our cognitive neuroscience work on how incoming bits of linguistic code are mapped onto available referents and on how they are related to the comprehender's conscious or unconscious interests.

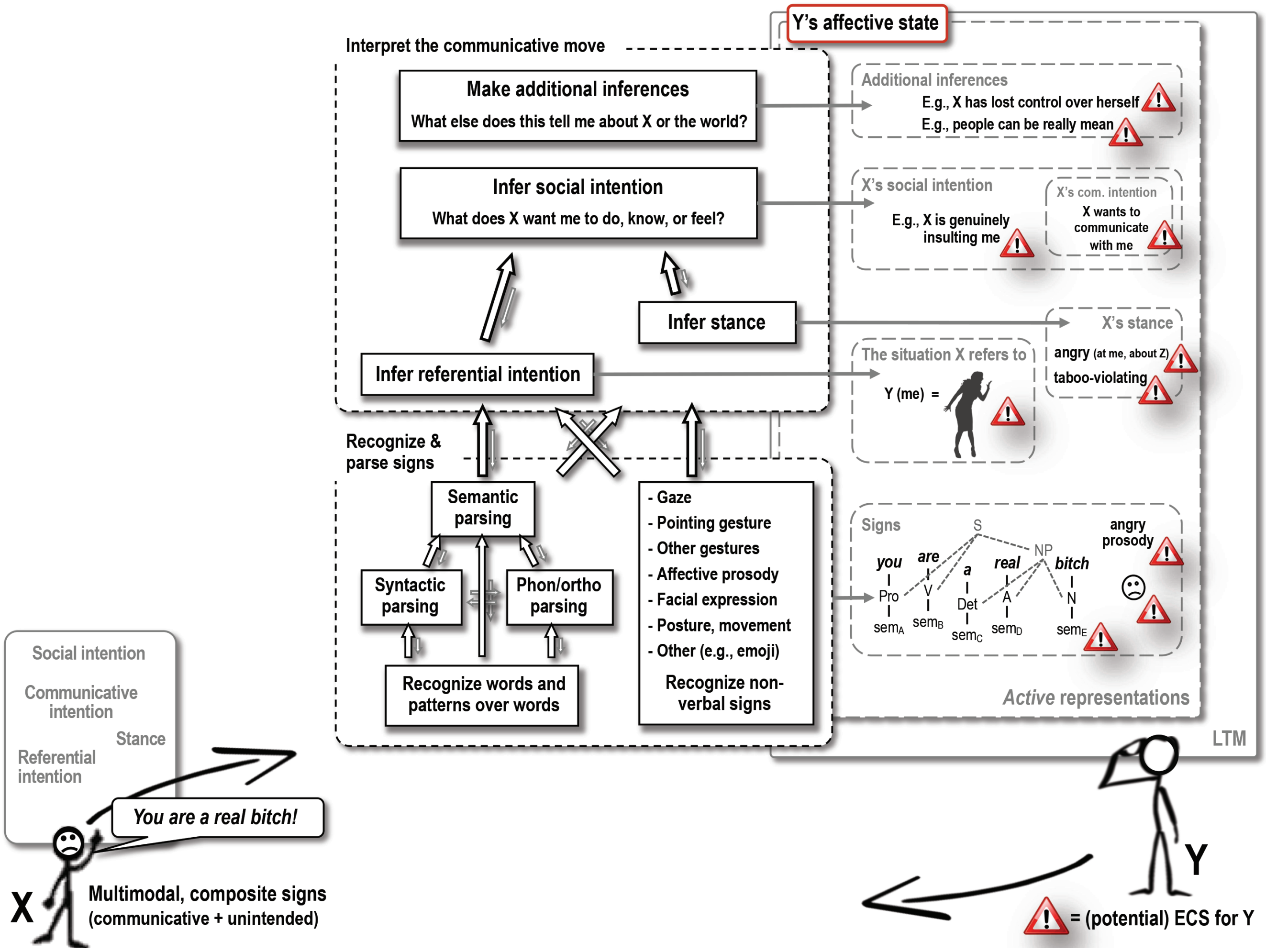

Figure 31.4 The ALC model. Mental processes and the associated retrieved or computed representations are expanded for addressee Y only. Y's computational processes draw upon (and add to) long-term memory (LTM) traces and involve currently active dynamic representations that reflect what is currently retrieved from LTM, composed from elements thereof and/or inferred from context, in response to the current communicative move. Y's active representations can be conscious or unconscious. ECS = emotionally competent stimulus; Phon/ortho parsing = phonological/orthographic parsing; X's com. intention = X's communicative intention. See van Berkum (2018, 2019a) for explanation. Adapted from van Berkum (2018, fig. 28.2) and van Berkum (2019a, fig. 29.1).

But language processing is not simply reactive. As argued elsewhere (van Berkum, 2013), people can and will have expectations about what speakers or authors will do at each of the levels relevant to language comprehension: the social intention, the referential intention, and the code used to realize them. In addition, as delineated in van Berkum (2009) in the context of the *Multiple-cause Intensified Retrieval* account of the N400, such expectations can be based on a wide variety of information sources, including, for example, associatively or semantically related prime words, scenario-based knowledge about the world activated by one or more words in the preceding text, a mental model of the situation being discussed, the immediately present physical situation, and such things as the discourse register and genre, the identity of the speaker, and the social goals believed to be pursued by him or her. Furthermore, everyday experience suggests that one's expectations can also be shaped by how we feel about what has been said before. With unfolding language, context is a very rich thing.

One early EEG study that illustrated the prediction of *specific upcoming bits of code* (van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005) probed for traces of word anticipation *before* the anticipated word came along (see also DeLong, Urbach & Kutas, 2005; Wicha, Moreno & Kutas, 2004; but see Nieuwland et al., 2018, for a failure to replicate the effect reported by DeLong et al., 2005). Participants listened to (Dutch) mini-stories such as "The burglar had no trouble locating the secret family safe. Of course, it was situated behind a ___," which in a paper-and-pencil cloze test were predominantly completed with one particular critical noun (in this case, *painting*, the Dutch translation of which is a neuter-gender word). To test whether such discourse-based lexical prediction would also occur "on-line" as part of real-time language comprehension, the EEG participants at this point first heard a gender-inflected adjective, whose syntactic gender either agreed with the anticipated noun, as in (a) "$big_{\textbf{neu}}$ but rather unobtrusive $painting_{\textbf{neu}}$" or did at that point not agree with this expected noun, as in (b) "$big_{\textbf{com}}$ but rather unobtrusive $bookcase_{\textbf{com}}$." Relative to the gender-congruent prenominal adjective in (a), the gender-incongruent adjective in (b) elicited a small but reliable ERP effect right at the inflection. Because this prediction effect hinged on the syntactic gender of an expected but not yet presented noun (*painting*$_{\textbf{neu}}$ in the example), and because the effect collapsed when the prior context sentence was removed, it suggested that discourse-level information can indeed lead people to anticipate specific upcoming words as the text unfolds. Follow-up experiments with the same gender-sensitive paradigm confirmed that such discourse-based lexical predictions cannot be reduced to the effects of simple or convergent lexical priming (Otten & van Berkum, 2008, 2009; Otten, Nieuwland, & van Berkum, 2007).[3]

Evidence for the anticipation of *upcoming reference* comes from an ERP study in which we examined the use of verb-based implicit causality information (van Berkum et al., 2007). When asked to complete a sentence fragment such as "David praised Linda because," readers and listeners will be inclined to continue the sentence with something about Linda, for example, "because she had done well." However, after "David apologized to Linda because," people tend to continue with something about *David* instead. In *person-1 verb-ed person-2 because* constructions, interpersonal verbs like *praise* and *apologize* thus supply information about whose behavior or state is the more likely immediate cause of the event at hand. Because this information is conveyed implicitly as part of the meaning of the interpersonal verb, it is usually referred to as *implicit causality*. In our experiment, we tested how rapidly readers were using this heuristic information as a context for anticipation, this by continuing the sentence with a bias-inconsistent pronoun ("David praised Linda because he"), and comparing the processing at this pronoun to its bias-consistent control ("Linda praised David because he"). Bias-inconsistent pronouns elicited a P600 effect, suggesting that as readers encountered the verb, their expectation for the sentence to continue with something about the person being praised was so strong that an expectation-inconsistent pronoun was momentarily taken as a processing—possibly morphosyntactic—error. The effect was replicated in a later study (van Berkum, de Goede, van Alphen, Mulder, & Kerstholt, 2013) and disappeared when readers were in a bad mood (consistent with other work on how mood affects cognitive processing; see e.g., Clore & Huntsinger, 2007).

In line with dominant interpretations of the N400 (Brouwer & Hoeks, 2013; Federmeier, 2007; Kutas & Federmeier, 2011; Lau, Phillips, & Poeppel, 2008; van Berkum, 2009), we think that the various discourse-dependent N400 effects obtained in many of our studies (e.g., Nieuwland, 2013, 2015; Nieuwland & van Berkum, 2005, 2006b; Otten & van Berkum, 2007; van Berkum et al., 2008; van Berkum, Hagoort, & Brown, 1999; van Berkum, Zwitserlood, et al., 2003) are best construed—at least partly—as instances of context-based anticipation as well. This includes our peanuts study (Nieuwland & van Berkum, 2006b), where, for example, a phrase like "The peanut was in love" elicited a large N400 effect on *in love* when presented in isolation, but *not* in the context of a cartoon-like story about a singing and dancing peanut—in the latter case, the precise mental model of the situation discussed prepared readers for *in love*, rather than for more typical features of peanuts. Context-based anticipation is presumably also why, for example, a word like *tattoo* in "I have a big tattoo on my back" elicits a larger N400 when the speaker has a stereotypical "upper-class" accent than when he or she has a stereotypical "lower-class" accent (van Berkum et al., 2008). Anticipations also arise during counterfactual language comprehension, which why a word that renders a counterfactual sentence false, like *USA* in "If NASA had not developed its Apollo Project, the first country to land on the moon would have been the USA," elicits a larger N400 compared to a word that renders the sentence true (*USSR*), despite the fact that *USA* is more strongly associated with all relevant concepts in the context (*NASA*, *Apollo Project*, *moon landing*) than *USSR* is (Nieuwland & Martin, 2012; see also Kulakova & Nieuwland, 2016).

In all, the evidence from our EEG studies on language processing confirms what should perhaps have been obvious anyway: we are memory-based forward-looking creatures, anticipating how the world might soon be—not just when we cross the street, but also when we process language.

5. Conclusion

In this chapter, we have reviewed our cognitive neuroscience research on how language is processed in context. We have explored how the unfolding linguistic code is related to the referential context, as well as how the code is related to the affective context, defined by the interests of the comprehender. In addition, we have examined some of the evidence for context-based anticipation during language processing.

We note that *context* has a wide range of interpretations that also depend on the grain size of the linguistic elements it is a context *for*, ranging from a single phoneme providing a context for the next, to one's interests and values providing a context for an entire discourse. We have also occasionally interpreted *context* differently, not as the synchronic or *enchronic* (Enfield, 2013) context for the processing or anticipation of a particular bit of code coming in, but as phylogenetically older systems that provide the basis for language, and allow language to *amplify* those older systems. These evolutionary and real-time contexts are related, though: since our map-making, affective, and anticipatory systems are amplified rather than replaced, they too provide the context for language processing as it unfolds in real time. Models such as the corticohippocampal theory of reference and the ALC model are models of how real-time language processing is interwoven with referential memory and affect.

The biggest addition brought by language may well be what people have focused on all along: it allows us to very precisely refer to states of affairs and refine our mental representations of what is, was, might, or could never be. However, that increased referential precision does its work in the same way that a simple pointing gesture can do its work (Tomasello, 2008; van Berkum, 2018, 2019a): by working out the exact referent, by inferring why the speaker wants to draw our attention to this in the first place, by relating both to what we care about as we navigate the physical and social world, and by responding affectively in appropriate ways. The increased referential precision doesn't just allow us to state that the elephant on the left is probably the easier target or that berries can be found in some particular spot near the river. The referential power of language also allows us to, for fun or science, create fictional worlds where peanuts can be in love. It allows us to define institutions, declare marriage, and denominate some individuals as presidents. And it allows us to discuss people's thoughts, feelings, and behavior, so as to realize some of our social intentions by evaluating—possibly even gossiping about—those of others. As such, the increased referential power that comes with language has not only massively amplified what we can achieve as the map-making, affective, and forward-looking animals that we are, but it is also deeply interwoven with our social and moral nature.

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NOTES

1. Neural oscillatory evidence for hippocampal involvement has yet to be found, but hippocampal oscillatory activity may not be detectable in EEG recordings (da Silva, 2013).
2. The negativity observed by Otten et al. (2016) had a slightly more anterior distribution than is typical for an N400 effect; this might reflect a different set of neural generators, but may also arise from overlap with a posteriorly distributed LPP effect.
3. These later studies also indicated that the exact ERP signature of prediction mismatch varied, for reasons we do not fully understand. A large-scale pre-registered replication study of van Berkum et al. (2005) is currently ongoing (supervised by M.S.N.) to explore the stability of that specific ERP effect.

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