57 Neuropragmatics

PETER HAGOORT AND STEPHEN C. LEVINSON

ABSTRACT Linguistic expressions are often underdetermined with respect to the meaning that they convey. That is why context is needed to establish the message that is intended to be communicated by the linguistic expressions that are used. Sometimes context information is explicitly provided, but often it relies on implicit background knowledge shared between speaker and listener. The context of communication needs to be invoked in understanding and producing linguistic codes. What is required, in addition to the linguistic code itself, to determine the meaning of an expression is usually referred to as pragmatics. The neurobiology of pragmatics is an area that has come under investigation only recently. Here we discuss central aspects of pragmatics. On the basis of recent functional MRI (fMRI) studies, it has become clear that the theory of mind network is involved in making the step from coded meaning to what is often called "speaker meaning," that is the intended message for the listener. Event-related potential studies have investigated whether pragmatic processing is superimposed on and follows in time the computation of coded meaning or, alternatively, whether context information is immediately integrated with lexical, syntactic, and semantic sources of information. On the whole, the evidence supports the immediacy assumption, suggesting that linguistic and nonlinguistic context information is immediately used for utterance interpretation. However, quite some individual variation is found in different aspects of pragmatic processing.

Neurobiological models of language not only need to address the circuitry that is crucial for encoding and decoding the content of an utterance, but they also need to specify the neural infrastructure for inferring what the speaker intended to communicate by uttering a sentence (i.e., speaker meaning; Grice, 1989; Noveck & Reboul, 2008). This is what we broadly refer to as neuropragmatics (Bambini, 2010; Bara, 2010). We will first discuss what is covered by the term *pragmatics* and why it is crucial in an account of human communication and language. This is followed by an overview of recent studies on the neural basis of pragmatics.

Pragmatics

Pragmatics is the study of the way in which context, including the discourse, beliefs, and inferences of participants, contributes to the meanings of utterances (see, e.g., Levinson, 1983; Sperber & Wilson, 1987). The mechanisms involved are diverse, but they give rise to substantial inferences that are not actually coded in what is said. Consider the following interchange:

A: Hey, I wonder who ate some of the chocolates I was going to give to Anne?
B: Oh, I heard the kids in the kitchen earlier.

From A's utterance, one may infer that (the parentheticals indicate some of the different categories of pragmatic inference referred to later):

(1) A wants to know who is responsible for eating some of the chocolates (speech act conditions).
(2) A thinks B might know the answer to his implied question, knows about the existence of the chocolates, and so on (audience design: utterances are formulated and adapted for specific listeners).
(3) A thinks that not all of the chocolates were eaten (scalar implicature from the use of *some*).

Likewise, from B's utterance in the context of A's question much further information can be inferred:

(4) B doesn't know for sure who ate some of the chocolates, but B is nevertheless trying to provide some kind of answer (adjacency pair constraint: answers should follow questions; Grice's maxim of relevance).
(5) B knows or guesses that A thinks the chocolates were in the kitchen (bridging inference, audience design).
(6) B is suggesting that perhaps the kids ate some of the chocolates (indirect speech act, conversational implicature), via additional premises like "kids tend to do naughty things" (common ground: implicit background knowledge shared between speakers and listeners).

None of these inferences are logical deductions from what is said. They can only be derived by making additional assumptions about the purposes and intentions with which we engage in verbal interaction and about common understandings about how we should use language. For example, other things being equal, we assume that people will recognize our speech acts (questions, requests, assertions, accusations, etc.) even though they are often not coded directly—here A's *I wonder who* is not syntactically a question, but rather specifies a precondition for asking one (the basis for inference 1 above), which A thinks should be enough for B to recognize the intention (inference 2 above). A doesn't seem to think all the chocolates have been eaten (3 above), because otherwise he wouldn't have said *some of the chocolates—some* means literally "at least one" so is compatible with "all" (cf. *some in fact all of the professors are stupid*), but since *all* wasn't said, the contrast suggests "not all."

Even more elaborate are the inferences we attribute to B's utterance, largely because of its position immediately after A's. If A's utterance is an indirect question, given that questions should be followed by answers, we try and interpret B's response as an indirect answer (inference 4), suggesting specifically that the kids may be to blame (inference 6). That in turn requires lots of further assumptions, like the chocolates being in the kitchen (inference 5), while drawing on common presumptions like the possible moral turpitude of younger members of the species, and so forth (6).

What is clear from any such little interchange is that what is coded in words and linguistic constructions far underdetermines what is obviously meant or intended: meaning in a broad sense is an iceberg, with the little linguistically coded part riding on a large submersed mountain of mutual inference.

Not all the things we infer from utterances come loaded with this intentional baggage. For example, we may detect from an accent that a speaker is not a native English speaker, or on the telephone from the acoustics that the speaker is a woman—these are usually not part of what the speaker is trying to communicate. The philosopher Grice (1957) made an important distinction between the kind of meaning that is intended to be communicated ("nonnatural meaning," or meaning-nn) and the kind of meaning that is simply conveyed unintentionally ("natural meaning"). He defined "nonnatural meaning" as the effect a communicator intends to cause in a recipient just by getting the recipient to recognize that intention: for example, I can yawn (itself a potential natural symptom of tiredness) in such a way that you can recognize that I am finding you boring. The intention-laden yawn is for Grice (and the pragmaticist in general) the curious phenomenon at the heart of human communication; when we use words we use them in the same kind of heavily intentional environment, where the choice of expressions are scrutinized for their underlying purpose and intentions. In the language domain, meaning-nn amounts to a theory of *speaker meaning*—what the speaker intends to achieve by the use of his or her utterance in a specific context, which can contrast with *sentence meaning*, what is abstractly coded and independent of context.

Grice's theory of meaning sought to characterize the whole domain of intentional communication, but it provides no mechanisms for recognizing communicative intentions. Here the levers seem to be provided by a wide range of background conventions or understandings. For example, we advance our communicative purposes in conversation by producing utterances in turn, where each utterance can be attributed with at least one main point or speech act (Searle, 1969)—so that, for example, one may recognize in A's turn above a question, which will require an answer in response.

Yet another kind of lever for making inferences in conversation is a general presumption of rational cooperation. Grice's (1975) second great contribution was the theory of conversational implicature, which spelt out some of the parameters of this presumptive cooperation in terms of four main "maxims of conversation." B's utterance in the interchange above (*Oh, I heard the kids in the kitchen earlier*) has no obvious connection to A's. But we make the assumption that A and B are trying to aid their mutual conversational undertaking, and that allows a range of detailed inferences. Grice posits a maxim of relevance, which requires a timely and pertinent response (hence the need to figure out how B's utterance ties to A's). He also posits a maxim of quantity, specifying that information provided should be not too much nor too little for the purposes in hand: a *Who did it?* question can be succinctly answered by a name like *Bill*, for example. Here there seem to be quite specific rules of thumb that can guide pragmatic inference. For example, the maxim of quantity presupposes some brevity metric, and linguistic systems provide sets of alternates, which will typically be of roughly equal brevity, for example, {*white, red, yellow, blue, ...*}. By the maxim of quantity, saying *He's waving a white flag* can thus be said to suggest—or *conversationally implicate*, as Grice would have it—that the flag is purely white; if it had been white, blue, and red, by the maxim of quantity requiring sufficient information, you should have said so (see Levinson, 2000). Further, such sets of alternates are often ordered by informativity, or forming ordered scales; for example <*all, most, many, several, some*>, <*must, may*>, <*and, or*>, etc. Here informationally stronger items to the left entail items further to the right: *the kids ate all the chocolates* entails "the kids ate (at least) some of the chocolates." We can now state one rule for generating general pragmatic inferences, so-called *generalized conversational implicatures* (or more specifically here, *scalar implicatures*), namely, that asserting a weaker item on a scale conversationally implicates a stronger item doesn't obtain (otherwise, by the maxim of quantity, you should have said the stronger one). That's the reason that we can make inferences like (3) from the little interchange between A and B above.

Another lever is a background assumption of audience design. When we refer to persons or things, we use the terms we think the recipient will be able to use to recognize the referent, choosing between *Mike, the author of "The Ethical Brain," the head of the Sage Centre,* etc. In our snippet above, the definite articles in *the chocolates, the kitchen,* and *the kids* implicate the mutual recognizability of the referents (inference 2 above). Normally, we introduce new inanimate referents with indefinite articles, and thereafter refer to them with definite ones. But we may also introduce assumptions without ever making overt reference to them, as in *We're so sorry we're late. Our hire car broke down; the steering wheel came off,* where the definite phrase *Our hire car* introduces the fact that we hired a car, and *the steering wheel* has to be understood as part of the same car (Clark, 1996). We trade all the time on presumed "common ground," assuming that we'll both keep track of references previously introduced, and that we can use stereotypes (like the naughtiness of kids) as premises in unarticulated inferences.

This brief introduction to the scope of pragmatic inference already makes clear, first, how fundamental the role of pragmatic inference is in language understanding, and second, the extent to which it depends massively on theory of mind, and specifically on reasoning about the other's purposes and intentions, together with constant updating of what we think our recipients presume or know (or do not know), and what we think they can infer from what we implicate but do not say. Pragmatics is, in other words, the science of the understood but unsaid.

The neural infrastructure for pragmatics in language

Despite the central contribution of pragmatic inferences to communication, most research on the neurobiology of language has focused on either single-word processing or on the syntactic and semantic operations involved in decoding the content of an utterance. Perisylvian cortex, with a left-hemisphere dominance, is known to be crucial for decoding propositional content (Hagoort, 2005, 2013; Hagoort & Poeppel, 2013). However, as we have seen above, communication involves much more than this. Knowledge about context and speaker needs to be invoked to infer the intended message (speaker meaning) and to engage in successful communication (Bambini, 2010; Levinson, 2000). Relatively few studies have investigated the neural infrastructure for effective communication beyond the core linguistic machinery for word retrieval, syntax, and semantics. Many aspects of pragmatics that we discussed above have not yet been investigated at the level of brain organization. Here we will review and summarize our limited current knowledge in the domain of neuropragmatics.

Recent studies investigated different aspects of communicative intentions, such as conversational implicatures and indirect requests. Bašnáková et al. (2013) contrasted direct and indirect replies—two classes of utterances whose speaker meanings are more and less similar to their coded meaning. In their study, participants listened to natural spoken dialogue in which the final and critical utterance—for example, "It is hard to give a good presentation"—had different meanings depending on the dialogue context and the immediately preceding question. This critical utterance either served as a direct reply (to the question "How hard is it to give a good presentation?") or an indirect reply (to "Did you like my presentation?"). One of the major motivations for speakers to reply indirectly in conversations is to mutually protect one another's public self (e.g., Brown & Levinson, 1987; Goffman, 1967; Holtgraves, 1999). Half of the indirect utterances represented such emotionally charged face-saving situations, such as attempts not to offend the person asking the question. The other half of the indirect replies represented more neutral situations, in which the speaker's motivation for indirectness was simply to provide more information than just a simple "no." In the indirectness effect, there were activations in the medial prefrontal cortex (mPFC) extending into the right anterior part of the supplementary motor area, and in the right temporoparietal junction (TPJ), a pattern typical for tasks that involve mentalizing based on a theory of mind (ToM; Amodio & Frith, 2006; Mitchell, Macrae, & Banaji, 2006; Saxe, Moran, Scholz, & Gabrieli, 2006). Although the exact role of all the individual ToM regions is not yet clearly established, both mPFC and right TPJ constitute core regions in ToM research (Carrington & Bailey, 2009). The most specific hypothesis about the role of the posterior part of (right) TPJ (Mars et al., 2012) in the mentalizing network is that it is implicated in mental state reasoning, that is, thinking about other people's beliefs, emotions, and desires (Saxe, 2010). Activation in the right TPJ also correlates with severity of autism in a self-other mental state reasoning task (Lombardo, Chakrabarti, Bullmore, & Baron-Cohen, 2011).

The mPFC cortex is a large cortical region with a variety of roles characteristic of social cognition (Amodio & Frith, 2006; Saxe & Powell, 2006). The peaks of the activation in the Bašnáková et al. study (2013) fall in the anterior and posterior rostral divisions, which are associated with complex sociocognitive processes such as mentalizing and thinking about the intentions of others or about oneself (Amodio & Frith, 2006). Interestingly, the involvement of these regions is also consistently observed in discourse comprehension (e.g., Mar, 2011; Mason & Just, 2009). This might come as no surprise, since it is likely that the motivations, goals, and desires of fictional characters are accessed in a similar manner as with real-life protagonists (Mar & Oatley, 2008). In fact, an influential model from the discourse-processing literature (Mason & Just, 2009) ascribes the dorsomedial part of the frontal cortex and the right TPJ a functional role as a *protagonist perspective network*, which generates expectations about how the protagonists of stories will act based on understanding their intentions.

A recent fMRI study on the processing of indirect requests (van Ackeren, Casasanto, Bekkering, Hagoort, & Ruschemeyer, 2012) confirmed the role of the ToM network in inferring speaker meaning. Participants were presented with sentences in the presence of a picture. In one condition, the sentence in combination with the picture could be interpreted as an indirect request for action. For example, the utterance "It is hot here" combined with a picture of a door is likely to be interpreted as a request to open the door. However, the same utterance combined with the picture of a desert will be interpreted as a statement. Van Ackeren et al. found that sentences in the indirect-request condition activated the ToM network much more strongly than the very same sentences in the control conditions with the same pictures and sentences but without the possibility to interpret the sentence in the context of the picture as an indirect request. The recognition of a speech act induced by an utterance in combination with its context requires the inferential machinery instantiated in the ToM network. Interestingly, van Ackeren et al. (2012) also found action-related regions more strongly activated in the indirect request condition. The indirect request for action seems to induce action preparation automatically, even in sentences that do not contain any action words. For a summary of the results, see figure 57.1.

In their fMRI study on conversational implicatures, Jang et al. (2013) manipulated the level of explicitness in question-answer pairs, from very explicit (A: "Is Dr. Smith in his office now?" B: "Dr. Smith is in his office now") to highly implicit (A: "Is Dr. Smith in his office now?" B: "The black car is parked outside the building"). The implicit answers generated stronger activations in mPFC and posterior cingulate cortex. The involvement of these areas can be attributed to the mentalizing operations subserved by the ToM network, although in this study TPJ was not found to be activated in relation to the conversational implicatures. In addition, the angular gyrus and the anterior temporal lobes were more strongly activated, presumably due to the top-down influence on processing of the different concepts in the answers (Binder & Desai, 2011; Patterson, Nestor, & Rogers, 2007).

Another type of conversational implicature is irony. Understanding irony requires inferring the speaker's attitude towards the linguistic expression (e.g., "what a wonderful talk" said ironically to convey that the speaker found the talk quite awful). A handful of studies on irony (for a review, see Spotorno, Koun, Prado, Van der Henst, & Noveck, 2012) reported mPFC involvement. So far, only one study (Spotorno et al., 2012) reported activation in TPJ. Spotorno et al. (2012) had their participants read stories in which the critical sentence was either a literal or an ironic statement. They found stronger activation for the target sentences in the ironic stories compared to the literal stories in all four regions of the ToM network: the right TPJ, the left TPJ, the mPFC, and the precuneus. Interestingly, the authors also report an increased functional connectivity between the ventral mPFC and the left inferior frontal gyrus for the ironic target sentences, suggesting some form of interaction between areas for mentalizing and semantic unification (Hagoort, 2013).

As we discussed above, meaning broadly construed is an iceberg, with the linguistically coded part riding on a large submersed mountain of mutual inference. This mutual inference is also at stake in situations where the linguistic code is absent. Recent studies investigated how human communication develops in a novel communicative action for which the constraints from coded meanings are lacking (Blokpoel et al., 2012; de Ruiter et al., 2010; van Rooij et al., 2011). The results of these studies indicate that human communication relies on inferential mechanisms shared across interlocutors (Stolk et al., 2013), rather than on sensorimotor brain-to-brain couplings (Rizzolatti & Graighero, 2007). It was found that the creation of novel shared symbols upregulates activity in the right temporal lobe across pairs of communicators, and over temporal scales unrelated to transient sensorimotor events (Stolk et al., 2013). These results suggest that this part of the brain supports the updating of common ground during a communicative interaction.

Although the number of studies on the neuropragmatics of language is still limited, there is a remarkable consistency in the finding that understanding the communicative intent of an utterance requires mentalizing. Since the linguistic code underdetermines speaker meaning, the ToM network needs to be invoked to get from coded meaning to speaker meaning. Despite the great popularity of the view that the mirror neuron system is sufficient for action understanding (Rizzolatti & Sinigaglia, 2010), this system does not provide the crucial neural infrastructure for inferring speaker

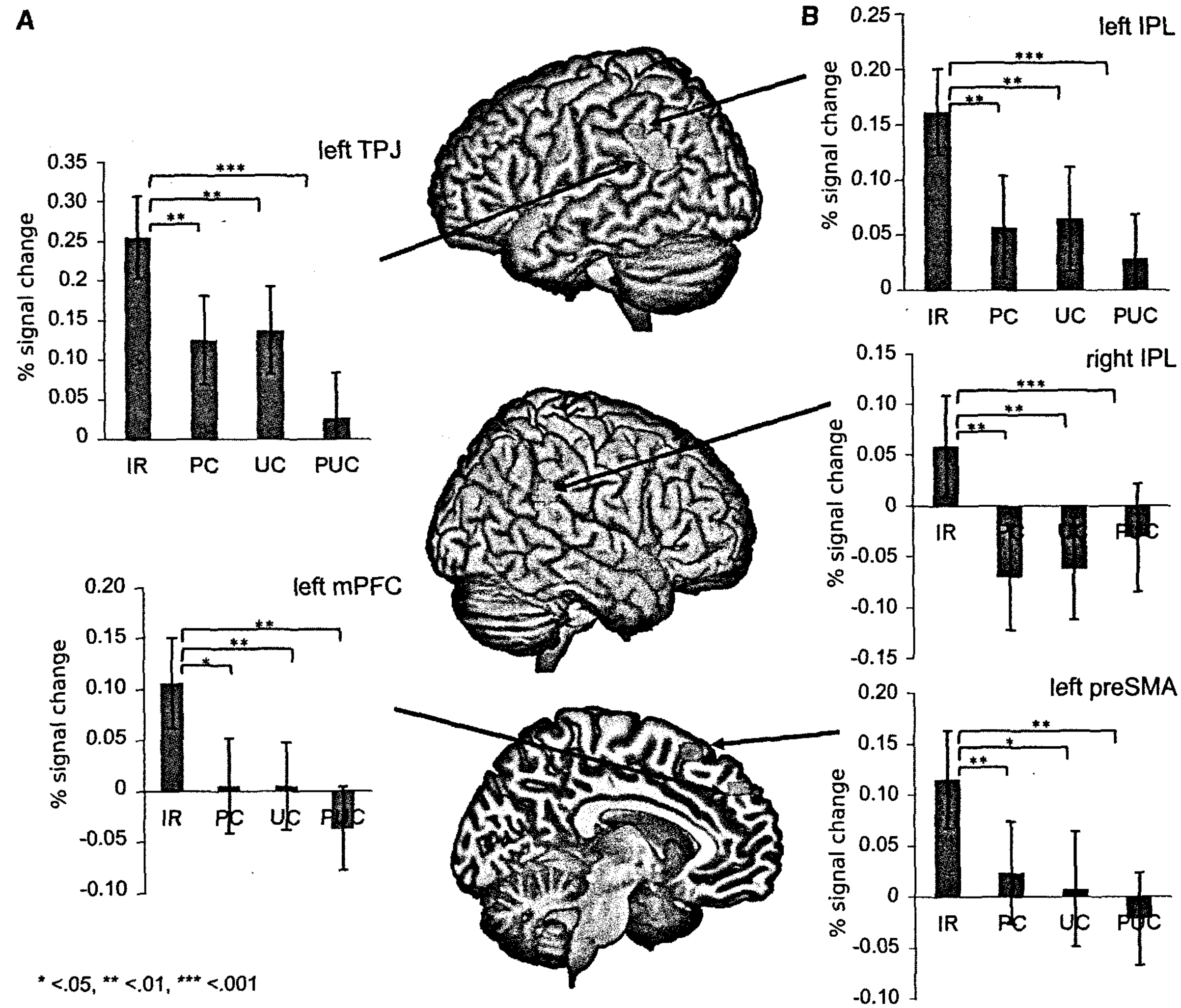

FIGURE 57.1 Regions of interest (ROIs) were interrogated for activations to an indirect request (IR) for action (as in "It is hot here" in the presence of a picture of a window) relative to three control conditions: PC (picture control), UC (utterance control), and BC (baseline control). The image shows all ROIs superimposed on a brain template. The bar diagrams illustrate mean percent signal change for each condition. The error bars depict the standard error. (A) Green ROIs show regions from the theory of mind (ToM) localizer (medial prefrontal cortex, mPFC; and temporoparietal junction, TPJ). (B) Red ROIs refer to regions that were activated during action execution (pre-supplementary motor area, preSMA; bilateral inferior parietal lobule, IPL; van Ackeren et al., 2012; reprinted with permission). (See color plate 50.)

meaning. Next to core areas for retrieving lexical information from memory and unification of the lexical building blocks in producing and understanding multiword utterances, other brain networks are needed to realize language-driven communication to its full extent.

The immediacy of pragmatic processing

A central issue of debate is to what extent pragmatic inferences are generated automatically and by default (Levinson, 2000) or, alternatively, are linked with processing effort and increased processing time, as is claimed to follow from the relevance theory of Sperber and Wilson (1995; cf. Noveck & Reboul, 2008). The area in which the alternative accounts are tested most explicitly is that of scalar implicatures. For example, the quantifier *some*, although logically equivalent to *all*, is pragmatically often interpreted as *some but not all* (see above). The speaker is assumed to use *some* for a reason, which is to convey information that would not be provided by *all* (Grice's maxim of quantity). The question is whether scalar implicatures are computed by default, or only if licensed by context. In the first case, a term such as *some* will automatically be interpreted pragmatically, that is, as *some but not all*. In the latter case, this will need to be induced by context. So far, most studies on the processing of scalar implicatures were behavioral. Only a few studies have exploited electrophysiological brain responses to investigate the processing of scalar implicatures (Hartshorne, Snedeker, & Kim, 2013; Nieuwland, Ditman, & Kuperberg, 2010; Noveck & Posada, 2003). Nieuwland et al. (2010) investigated how quickly pragmatic knowledge is recruited during informative and underinformative usage of quantifiers. In their study, they compared the ERPs to critical words in sentences with an underinformative usage of *some* (e.g., *"Some people have lungs, ..."*) to those with an informative usage (e.g., *"Some people have pets, ..."*). The results showed quite some individual variation. Participants who scored high on scales for pragmatic competence showed an N400 effect to the target words (*lungs/pets*) in the underinformative compared to the informative statements (i.e., to *lungs* vs. *pets*). Based on the pragmatic interpretation of *some* (*some but not all*), they showed an immediate N400 response when this reading was violated (as in the case of "lungs"). No such effect was observed in participants who scored low on pragmatic ability. This result suggests that scalar implicatures can be immediately incorporated during sentence comprehension, albeit that this is done with quite a bit of individual variation.

Hartshorne, Snedeker, and Kim (2013) introduced an additional control, using "only." In "*Only some politicians are corrupt,*" the semantic reading that in fact all politicians are corrupt is excluded. This is different for *"Some politicians are corrupt,"* which could be extended as follows, *"Some politicians, in fact all politicians, are corrupt."* With the addition of this control condition, they compared declarative sentences such as (1) "Addison ate some of the cookies before breakfast this morning, and *the rest* are on the counter," with a conditional version as in (2) "If Addison ate some of the cookies before breakfast this morning, then *the rest* are on the counter." The noun phrase *the rest* in (1) is only felicitous if Addison has not eaten all of the cookies, which is what the scalar implicature entails. The assumption is that, instead, conditional sentences suppress the implicature (Noveck, Chiercia, Chevaux, Guelminger, & Sylvestre, 2002). The crucial results in this study are the interactions between the "declarative/conditional" and the "some/only some" conditions. The ERP results showed the absence of an interaction to *some*. However, at *the rest* an interaction was observed. The authors conclude that although context did not affect the processing of the quantifier that triggered the scalar implicature (*some*), it did affect the processing of subsequent words in the sentence.

Overall, the results on scalar implicatures indicate that their processing costs are relatively minor, although some contextual modulation can be obtained with quite some individual variation. However, the number of studies is limited, and more definitive answers need to be based on further investigations.

Although scalar implicatures have been used as a test bed for alternative theoretical claims, many other studies investigated the influence of nonlinguistic contexts on sentence comprehension. These included information about the speaker (van Berkum, Van Den Brink, Tesink, Kos, & Hagoort, 2008), co-speech gestures (Özyürek, Willems, Kita, & Hagoort, 2007), and world knowledge (Hagoort, Bastiaansen, Hald, & Petersson, 2004). These studies found the same effects for nonlinguistic compared to linguistic information on the amplitude and latency of ERPs such as the N400. In addition, discourse information (Hald, Steenbeek-Planting, & Hagoort, 2007) and pragmatically licensed negations (Nieuwland & Kuperberg, 2008) influence the amplitude of the N400 at exactly the same latencies as semantic anomalies do. This suggests that both linguistic and nonlinguistic contexts have an immediate impact on the interpretation of an utterance (Hagoort & van Berkum, 2007).

In summary, the empirical evidence is still inconclusive with respect to the speed and automaticity of the inferential steps that are needed to close the gap between coded meaning and speaker meaning (Noveck & Reboul, 2008). Very likely there are developmental and individual differences in the degree to which pragmatic inferences are automatically integrated with lexical, syntactic, and semantic processing operations. At the same time, it is clear that a full understanding of the neurobiological infrastructure for language requires a specification of the neural circuitry that establishes the common ground between speaker and listener (Clark, 1996) and that gets us from coded meaning to speaker meaning.

Conclusion

The neurobiology of language has focused mainly on lexical and sublexical processes, and beyond the single-word level, especially on syntactic operations. Pragmatic aspects of language have become part of the neurobiological agenda only recently (cf. van Berkum, 2009). As we have shown, this is a necessary step if we want to understand how linguistic codes get their communicative value. Moreover, integration of neuropragmatics into the overall picture is helpful for avoiding theoretical pitfalls, such as the idea that sensorimotor simulation and the mirror neuron system are even close to being sufficient for language understanding. Finally, in addition to core areas for language in mainly left perisylvian cortex, additional neuronal circuits are involved to get from coded meaning to speaker meaning.

REFERENCES

Amodio, D. M., & Frith, C. D. (2006). Meeting of minds: The medial frontal cortex and social cognition. *Nat Rev Neurosci*, 7(4), 268–277.

Bambini, V. (2010). Neuropragmatics: A foreword. *Ital J Linguist*, *22*(1), 1–20.

Bara, B. (2010). *Cognitive pragmatics*. Cambridge, MA: MIT Press.

Bašnáková, J., Weber, K., Petersson, K. M., van Berkum, J., & Hagoort, P. (2013). Beyond the language given: The neural correlates of inferring speaker meaning. *Cereb Cortex*. doi:10.1093/cercor/bht112

Binder, J. R., & Desai, R. H. (2011). The neurobiology of semantic memory. *Trends Cogn Sci*, *15*(11), 527–536.

Blokpoel, M., van Kesteren, M., Stolk, A., Haselager, P., Toni, I., & van Rooij, I. (2012). Recipient design in human communication: Simple heuristics or perspective taking? *Front Hum Neurosci*, *6*, 253.

Brown, P., & Levinson, S. C. (1987). *Politeness: Some universals in language usage*. Cambridge, UK: Cambridge University Press.

Carrington, S. J., & Bailey, A. J. (2009). Are there theory of mind regions in the brain? A review of the neuroimaging literature. *Hum Brain Mapp*, *30*(8), 2313–2335.

Clark, H. H. (1996). *Using language*. Cambridge, UK: Cambridge University Press.

De Ruiter, J. P., Noordzij, M. L., Newman-Norlund, S., Newman-Norlund, R., Hagoort, P., Levinson, S. C., & Toni, I. (2010). Exploring the cognitive infrastructure of communication. *Interact Stud*, *11*(1), 51–77.

Goffman, E. (1967). *Interaction ritual: Essays on face-to-face interaction*. New York, NY: Pantheon.

Grice, H. P. (1957). Meaning. *The philosophical review*, *66*(3), 377–388.

Grice, H. P. (1975). Logic and conversation. In P. Cole & J. L. Morgan (Eds.), *Syntax and semantics: Speech acts* (Vol. 3, pp. 41–58). New York, NY: Academic Press.

Grice, H. P. (1989). *Studies in the way of words*. Cambridge, MA: Harvard University Press.

Hagoort, P. (2005). On Broca, brain, and binding: A new framework. *Trends Cogn Sci*, *9*, 416–423.

Hagoort, P. (2013). MUC (Memory, Unification, Control) and beyond. *Front Psychol*, *4*, 416.

Hagoort, P., Hald, L., Bastiaansen, M., & Petersson, K. M. (2004). Integration of word meaning and world knowledge in language comprehension. *Science*, *304*, 438–441.

Hagoort, P., & Poeppel, D. (2013). The infrastructure of the language-ready brain. In M. A. Arbib (Ed.), *Language, music, and the brain: A mysterious relationship* (pp. 233–255). Cambridge, MA: MIT Press.

Hagoort, P., & van Berkum, J. (2007). Beyond the sentence given. *Philos Trans R Soc Lond B Biol Sci*, *362*(1481), 801–811.

Hald, L. A., Steenbeek-Planting, E. G., & Hagoort, P. (2007). The interaction of discourse context and world knowledge in online sentence comprehension. Evidence from the N400. *Brain Res*, *1146*, 210–218.

Hartshorne, J. K., Snedeker, J., & Kim, A. (2013). The neural computation of scalar implicature. Paper presented at the Annual Meeting of the Cognitive Science Society, Berlin, Germany.

Holtgraves, T. (1999). Comprehending indirect replies: When and how are their conveyed meanings activated? *J Mem Lang*, *41*, 519–540.

Jang, G., Yoon, S.-A., Lee, S.-E., Park, H., Kim, J., Ko, J. H., & Park, H.-J. (2013). Everyday conversation requires cognitive inference: Neural bases of comprehending implicated meanings in conversations. *NeuroImage*, *81*, 61–72.

Levinson, S. C. (1983). *Pragmatics*. Cambridge, UK: Cambridge University Press.

Levinson, S. C. (2000). *Presumptive meanings*. Cambridge, MA: MIT Press.

Lombardo, M. V., Chakrabarti, B., Bullmore, E. T., & Baron-Cohen, S. (2011). Specialization of right temporoparietal junction for mentalizing and its relation to social impairments in autism. *NeuroImage*, *56*(3), 1832–1838.

Mar, R. A. (2011). The neural bases of social cognition and story comprehension. *Annu Rev Psychol*, *62*, 103–134.

Mar, R. A., & Oatley, K. (2008). The function of fiction is the abstraction and simulation of social experience. *Perspect Psychol Sci*, *3*(3), 173–192.

Mars, R. B., Sallet, J., Schuffelgen, U., Jbabdi, S., Toni, I., & Rushworth, M. F. S. (2012). Connectivity-based subdivisions of the human right "temporoparietal junction area": Evidence for different areas participating in different cortical networks. *Cereb Cortex*, *22*(8), 1894–1903.

Mason, R. A., & Just, M. A. (2009). The role of the theory-of-mind cortical network in the comprehension of narratives. *Lang Linguist Compass*, *3*(1), 157–174.

Mitchell, J. P., Macrae, C. N., & Banaji, M. R. (2006). Dissociable medial prefrontal contributions to judgments of similar and dissimilar others. *Neuron*, *50*(4), 655–663.

Nieuwland, M. S., Ditman, T., & Kuperberg, G. R. (2010). On the incrementality of pragmatic processing: An ERP investigation of informativeness and pragmatic abilities. *J Mem Lang*, *63*(3), 324–346.

Nieuwland, M. S., & Kuperberg, G. R. (2008). When truth is not too hard to handle. *Psychol Sci*, *19*(12), 1213–1218.

Noveck, I. A., & Posada, A. (2003). Characterizing the time course of an implicature: An evoked potentials study. *Brain Lang*, *85*(2), 203–210.

Noveck, I. A., & Reboul, A. (2008). Experimental pragmatics: A Gricean turn in the study of language. *Trends Cogn Sci*, *12*(11), 425–431.

Noveck, I. A., Chiercia, G., Chevaux, F., Guelminger, R., & Sylvestre, E. (2002). Linguistic-pragmatic factors in interpreting disjunctions. *Think Reasoning*, *8*, 297–326.

Özyürek, A., Willems, R. M., Kita, S., & Hagoort, P. (2007). On-line integration of semantic information from speech and gesture: Insights from event-related brain potentials. *J Cogn Neurosci*, *4*, 605–616.

Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nat Rev Neurosci, 8*(12), 976–987.

RIZZOLATTI, G., & CRAIGHERO, L. (2007). Language and mirror neurons. In M. G. Gaskell (Ed.), *Oxford handbook of psycholinguistics* (pp. 771–785). Oxford, UK: Oxford University Press.

RIZZOLATTI, G., & SINIGAGLIA, C. (2010). The functional role of the parieto-frontal mirror circuit: Interpretations and misinterpretations. *Nat Rev Neurosci, 11,* 264–274.

SAXE, R. (2010). The right-temporo-parietal junction: A specific brain region for thinking about thoughts. In A. Leslie & T. German (Eds.), *Handbook of theory of mind.* Philadelphia, PA: Psychology Press.

SAXE, R., MORAN, J. M., SCHOLZ, J., & GABRIELI, J. (2006). Overlapping and non-overlapping brain regions for theory of mind and self reflection in individual subjects. *Soc Cogn Aff Neurosci, 1*(3), 229–234.

SAXE, R., & POWELL, L. J. (2006). It's the thought that counts: Specific brain regions for one component of theory of mind. *Psychol Sci, 17*(8), 692–699.

SEARLE, J. R. (1969). *Speech acts: An essay in the philosophy of language.* Cambridge, UK: Cambridge University Press.

SPERBER, D., & WILSON, D. (1987). Précis of *Relevance: Communication and cognition. Behav Brain Sci, 10,* 697–710.

SPERBER, D., & WILSON, D. (1995). *Relevance: Communication and cognition* (2nd ed.). Oxford, UK: Blackwell.

SPOTORNO, N., KOUN, E., PRADO, J., VAN DER HENST, J. B., & NOVECK, I. A. (2012). Neural evidence that utterance-processing entails mentalizing: The case of irony. *NeuroImage, 63,* 25–39.

STOLK, A., NOORDZIJ, M. L., VERHAGEN, L., VOLMAN, I., SCHOFFELEN, J.-M., OOSTENVELD, O., ... TONI, I. (2013). Cerebral coherence between communicators marks the emergence of meaning. Paper presented at the 43rd Annual Meeting of the Society for Neuroscience, San Diego, CA.

VAN ACKEREN, M. J., CASASANTO, D., BEKKERING, H., HAGOORT, P., & RUESCHEMEYER, S.-A. (2012). Pragmatics in action: Indirect requests engage theory of mind areas and the cortical motor network. *J Cogn Neurosci, 24*(11), 2237–2247.

VAN BERKUM, J. J. A. (2009). The neuropragmatics of "simple" utterance comprehension: An ERP review. In K. Yatsushiro & U. Sauerland (Eds.), *Semantics and pragmatics: From experiment to theory.* Basingstroke, U.K.: Palgrave Macmillan.

VAN BERKUM, J. J. A., VAN DEN BRINK, D., TESINK, C., KOS, M., & HAGOORT, P. (2008). The neural integration of speaker and message. *J Cogn Neurosci, 20,* 580–591.

VAN ROOIJ, I., KWISTHOUT, J., BLOKPOEL, M., SZYMANIK, J., WAREHAM, T., & TONI, I. (2011). Intentional communication: Computationally easy or difficult? *Front Hum Neurosci, 5,* 1–18.