The brain is a prediction machine that cares about good and bad – Any implications for neuropragmatics?

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Experimental pragmatics asks how people construct contextualized meaning in communication. So what does it mean for this field to add *neuro-* as a prefix to its name? After analyzing the options for any subfield of cognitive science, I argue that neuropragmatics can and occasionally should go beyond the instrumental use of EEG or fMRI and beyond mapping classic theoretical distinctions onto Brodmann areas. In particular, if experimental pragmatics 'goes neuro', it should take into account that the brain evolved as a control system that helps its bearer negotiate a highly complex, rapidly changing and often not so friendly environment. In this context, the ability to predict current unknowns, and to rapidly tell good from bad, are essential ingredients of processing. Using insights from non-linguistic areas of cognitive neuroscience as well as from EEG research on utterance comprehension, I argue that for a balanced development of experimental pragmatics, these two characteristics of the brain cannot be ignored.*

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1. Pragmatics goes neuro, but how far exactly?

Pragmatics is often defined as the study of how linguistic properties and contextual factors interact in the interpretation of utterances (Levinson 1983; Sperber & Noveck 2004). Pragmaticists ask fundamental questions about contextualized meaning in communicative interaction – how does it work, how *can* it work, is there any systematicity to it that we can capture in a concise and illuminating way? *Experimental* pragmaticists pursue these questions by taking a processing perspective, i.e., by asking how contextualized meaning is constructed in the minds of actual language users (e.g., Sauerland & Yatsushiro 2009; Sperber & Noveck 2004; Noveck & Reboul 2008). So what about *neuro*pragmatics? What's with the prefix?

The introduction of neuroscience ideas in experimental pragmatics echoes a wider development in cognitive science, where classic information-theoretic ideas about the fundamental irrelevance of the specific 'hardware' (e.g., Fodor 1980; Newell 1982; Pylyshyn 1984)

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are giving way to a perspective in which the brain takes centre stage. However, as in other subfields of cognitive science that gradually begin to mind the brain, the prefix *neuro-* does not stand for a single approach. To see how it affects the endeavor of experimental pragmatics, it may be useful to first examine what neuro- can stand for in a cognitive science subfield anyway.

Neuro Lite approach. Here, researchers simply replace 'mind' by 'brain' (or 'mind/brain') to then carry on with their classic cognitive science business as usual, reasoning about the mind in terms of rules and representations, box-and-arrow flowchart models and, occasionally, explicit computational models. Even researchers who once deeply subscribed to the irrelevant hardware idea ('methodological solipsism', Fodor 1980) nowadays probably occasionally refer to the brain instead of the mind. But of course, apart from rhetorics, nothing really changes.

Instrumental approach. At the next level, neuroscience methods are used as additional tools in one's search for the functional architecture of the mind, without fundamentally caring about the brain. For example, one might use electroencephalography (EEG) or functional magnetic resonance imaging (fMRI) to settle an issue about whether two putative information processing stages (e.g., computing sentence meaning and speaker meaning) interact, operate independently, or are instantiations of the same mental process operating on different representations. The research questions are entirely formulated within the realms of classic cognitive science, and neuroscience measures are solely used to generate additional constraints on cognitive theorizing.

Modestly ontological approach. Here, the research agenda is still predominantly set by classic cognitive theories, but specific research questions now also target the brain. A good example of this is to ask about 'the neural substrate' of some process – say, pragmatic inferencing – by means of fMRI. Most commonly, what people try to do here is map their current classic flowchart (or, more rarely, computational) thinking onto systems-level neuroscience ideas, where networks of brain areas are *also* conceived of in terms of processing components and communication between them. So, instead of simply speaking about an 'inferencing system', terms like 'medial frontal cortex' and 'Brodmann area 10', as well as what we know about those brain areas from other work, also enter theorizing.

Deeply ontological approach. On the reasonable assumption that general principles of brain functioning are relevant to specific models of information processing, the research agenda here is also partly set by knowledge about the brain and how it evolved. For example, if top-down prediction and rapid valuation are fundamental systems-level operating principles of the brain, one would want to somehow accommodate (or at least consider accommodating) these ideas into one's thinking about mental processes X, Y and Z. Note that this is not a simple reductionist perspective in which all theories should be couched in the language of neurons and synapses – as argued by many (e.g., Marr 1982; Newell 1982), with a system as complex and layered as the brain, higher levels of description are simply essential. It's just that the specific theories at hand also take into account insights generated by modern cognitive neuroscience.[1]

So, what about neuropragmatics, then? Although particular research projects can incorporate aspects of each of these approaches, virtually all neuropragmatic studies so far, including my own, have 'gone neuro' in an instrumental and/or modestly ontological sense only. Is that bad? No. There is nothing inherently suboptimal in using Event Related Potentials (ERPs) to validate cognitive models, and in mapping such models onto brain areas – in fact, cognitive models can give much-needed direction to what otherwise would be mere shotgun empiricism with researchers staring at overwhelming neuroscientific data sets. Furthermore, research fields are always historically determined as well as in flux, and if, say, a predominantly instrumental neuro- approach is what currently works best within a particular field, given the goals it has set for itself, that's OK. Having said that, it is also obvious that any field dealing with mental processes would do wise to at least *occasionally* take a deep ontological neuro- approach, that is, reconsider its research agenda in the light of how we think the brain works, and why it works that way. After all, if additional insights from cognitive neuroscience are relevant to your concerns, why not enjoy them?

In the remainder of this paper, I'll make a case for the relevance to experimental pragmatics of two themes that are strongly emerging in cognitive neuroscience. One is the growing realization that the brain is a prediction machine. The second is that part of the brain's success is that it rapidly computes good and bad, or valence, to negotiate the physical and social environment. My intention is to convince at least some experimental pragmaticists that for a balanced development of their field, prediction and valence cannot be ignored. It's not that experimental pragmaticists should think about these two issues *all the time*. But at least some of them should do so some of the time.

2. Prediction

2.1. The brain is a fundamentally proactive device

We can find predictions in every corner of cognition. In motor behavior, for example, model-based predictions of the sensory consequences of intended actions are a crucial part of effective motor control (e.g., Wolpert & Flanagan 2001), and context plays an important role in selecting the right *forward model*. It is this sort of context-sensitive prediction that helps you lift an open carton of milk gracefully, and causes you to overshoot when lifting an empty carton that you thought was full. It is also behind that strange sensation when you step on an escalator that doesn't work.

In vision, we know from research on representational momentum that if you see a series of static pictures that together imply motion, such as an athlete jumping or a rocket launching itself into space, your brain prepares for the next picture in a way that betrays a forward model of the unfolding movement (Thornton & Hubbard 2002). Other work has shown that a crude initial analysis of the visual stimulus leads people to rapidly predict what they are about to see in full, and such predictions are fed back into early visual areas (e.g., Bar 2007; 2009a; Kveraga et al. 2007; Summerfield & Egner 2009). As in the motor domain, predictions are contextualized, such that the same fuzzy shape can leads people to predict, say, a hairdryer in a hair-salon context, but a water pistol in the context of children playing in the garden on a hot summer day.

And there's much more. At a somewhat more deliberate level, for example, we routinely use our Theory of Mind skills to predict what other people might do (Frith & Frith 2010). We plan everything from papers to summer vacations to military campaigns, and most of us continuously ruminate about our future. Even though we do not always put it to the best of uses, and although our deliberate anticipation skills have definite room for improvement (Covey 1989), we're all in all a pretty proactive species.

What ties all these observations together is the growing realization that a primary function of the brain is to predict its environment in space and time (Bar 2007; 2009a), and that the purpose of long-term memory is precisely to support such prediction (Schacter et al. 2007; Schooler & Anderson 1997). In neuroscience, the classic view of the brain as a fundamentally bottom-up device that hierarchically builds complex percepts by piecing together aspects of sensory input (e.g., from simple circular receptive fields to line segments to faces) is rapidly giving way to a very different perspective:

> The brain is no longer viewed as a transformer of ambient sensations into cognition, but a generator of predictions and inferences that interprets experience according to subjective biases and statistical accounts of past encounters (Mesulam 2008: 368).

In line with this change in perspective, models of detailed brain function are increasingly couched in terms of predictive coding and minimizing prediction error (e.g., Friston 2005; Mehta 2001; Rao & Ballard 1999; Summerfield et al. 2006). In a recent and influential theory of evoked brain response (Friston 2005), for example, perception is modelled as hierarchical Bayesian inference, with forward models at each level of the cortical hierarchy predicting the input at the lower level, and with lower level systems sending prediction error signals up the hierarchy, for short-term adjustment as well as learning. In this perspective, the brain is essentially making sense of its environment by *predicting what the latter should look like*, given the acquired and/or genetically hardwired models of how the environment behaved before.

Important to current concerns, neuroscience is moving towards predictive coding models of brain function for several functional reasons. One is that classic hierarchical bottom-up coding cannot deliver the speedy perceptions that real brains do (Mesulam 2008). A second, deeper reason is that the raw environmental signal is just too ambiguous and complex to deal with in a bottom-up fashion (Bar 2007; Friston 2005) – only predictive forward models allow us to segment, select and stabilize input so that we perceive stability and coherence in our environment (Bar 2007). So in all, our brains are not just proactive because it pays to anticipate upcoming events in a complex dynamic world. They are also proactive because the input would otherwise simply be too difficult to deal with efficiently.

2.2. Prediction in language comprehension

Given that language comprehension is realized by the brain and, moreover, is bound to recruit many evolutionarily pre-existing brain systems (e.g., Marcus 2008; Christiansen & Chater 2008; Levinson 2006), the above observations would lead one to expect that language comprehension is also strongly proactive. However, psycholinguistic research on sentence comprehension has long been dominated by the idea that language is *so* different from our other faculties that it just *has* to be subserved by uniquely adapted special-purpose hardware. Furthermore, if language is a generative system that allows people to express just about anything at any given moment, how could prediction ever work anyway? Wouldn't the system more often be wrong than right? And, importantly, wouldn't the total costs of being wrong be prohibitive? Wouldn't it just be better to wait until the input has fully unfolded?

Ideas such as these have prevented most processing-oriented language comprehension researchers from considering prediction as a central feature of the architecture (see Altmann 1997; Elman 1990; Federmeier & Kutas 1999 for notable exceptions). But when we look for prediction, we can find it in language comprehension just as well. For example, ERP experiments from our lab have revealed that, as they read or listen to an unfolding utterance, people routinely use their knowledge of the wider discourse context to predict specific upcoming words. In one of these studies (Van Berkum et al. 2005), participants listened to (Dutch) mini-stories such as (1a), 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 would at this point first hear a gender-inflected adjective whose syntactic gender either agreed with the anticipated noun, as in (1b), or did not agree with this expected noun, as in (1c).

(1) a. The burglar had no trouble locating the secret family safe. Of course, it was situated behind a…
b. … big$_{\mathrm{NEU}}$ but rather unobtrusive painting$_{\mathrm{NEU}}$
c. … *big*$_{\mathit{COM}}$ but rather unobtrusive bookcase$_{\mathrm{COM}}$

Relative to the gender-congruent prenominal adjective in (1b), the gender-incongruent adjective in (1c) elicited a small but reliable ERP effect right at the inflection, illustrated in Fig. 1. Because this prediction effect hinges on the idiosyncratic (hence memorized) syntactic gender of an expected but not yet presented noun, it suggests that discourse-level information can indeed lead people to anticipate specific upcoming words 'on-line', as a local sentence unfolds. In addition, the fact that such prediction can be probed via syntactic gender agreement suggests that the syntactic properties of those anticipated 'ghost' words can immediately begin to interact with locally unfolding syntactic constraints, such as the gender inflection on a prenominal adjective.

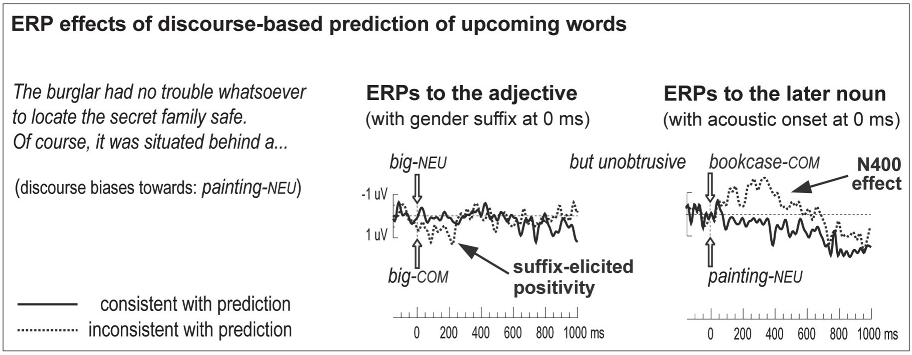

Figure 1. Left: The ERP effect to spoken adjectives whose morphosyntactic gender suffix did (solid line) or did not (dotted line) match discourse-based expectations for specific upcoming nouns (e.g., the neuter Dutch equivalent of *painting*, preceded by a prenominal adjective with common gender suffix). Right: The N400 effect elicited by the actual spoken nouns presented later in the sentence, with a coherent but less expected noun (e.g., *bookcase*, dotted line) eliciting a much larger N400 than the discourse-predictable noun (e.g., *painting*, solid line). Acoustic onset of the critical suffix (left) or later noun (right) is at 0 ms.

In follow-up research (Otten & Van Berkum 2008; 2009; Otten et al. 2007), we examined whether these discourse-based predictions were being driven by a precise message-level representation of the discourse (as had been assumed by Van Berkum et al. 2005), or whether they could be reduced to a somewhat simpler predictive mechanism involving scenario-based or convergent lexical priming (e.g., *burglar*, *safe* and *behind* jointly predicting *painting*, regardless of the specific assertions being made in the story). The ERP results actually suggest that in the agreement-sensitive paradigms used here, predictions critically hinge on the precise message conveyed so far. Moreover, it is not merely highly skilled language users that exhibit such discourse-based anticipation: readers with rather low verbal working memory do so just as well (Otten & Van Berkum 2009).

Research in another comprehension paradigm (Koornneef & Van Berkum 2006; Van Berkum et al. 2007) also suggests that language users routinely look ahead as they make their way through an utterance. In this paradigm we made use of *implicit causality*, stereotypical knowledge associated with verbs like *praise* or *apologize*. When asked to complete a fragment such as *David praised Linda because...*, readers and listeners will be inclined to continue with something about Linda, e.g., *...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 behaviour or state is the more likely immediate cause of the event at hand. In our experiments, we tested whether this probabilistic information can rapidly lead readers to anticipate, on the fly, about whom the sentence will continue in the because-clause. We did this by occasionally continuing the because-clause with an expectation-*in*consistent referential pronoun (as in 2b), and by comparing the processing at this pronoun to its expectation-consistent control (2a).

(2) a. Linda praised David because he…
b. David praised Linda because he…

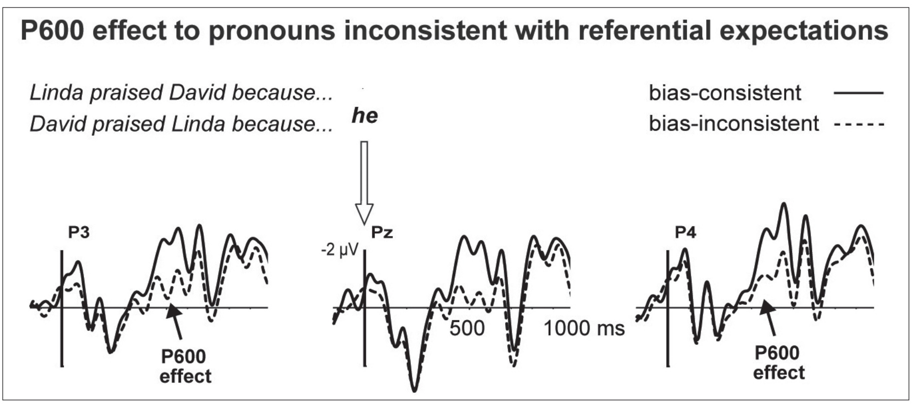

Figure 2. ERPs to singular pronouns whose gender-marking was consistent (solid line) or inconsistent (dotted line) with the implicit causality bias of a preceding verb. Bias-inconsistent pronouns elicit a P600 effect, suggesting that the semantic/referential bias briefly caused readers to blame the morphosyntax. Onset of the written pronoun is at 0 ms.

Expectation-inconsistent pronouns such as in (2b) indeed came as an unpleasant surprise, causing readers to slow down right at or shortly after the critical word (Koornneef & Van Berkum 2006). Furthermore, as displayed in Fig. 2, the processing costs of expectation-inconsistent pronouns also emerged in ERPs, as an early P600 effect (Van Berkum et al. 2007). Taken together, these various processing costs of bias-inconsistent pronouns show that people were at that point in the sentence indeed expecting information about somebody else. Furthermore, the observation of a P600 effect is consistent with the idea 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 actually briefly taken as a morpho-syntactic *error* (see Van Berkum et al. 1999, for a similar phenomenon).

The above two paradigms were specifically *designed* to probe for anticipation. However, standard semantic anomaly N400 effects in utterances such *He buttered the bread with socks* (Kutas & Hillyard 1980) can also be taken to reflect the workings of a predictive brain. According to a widely shared model of the N400 (Kutas & Federmeier 2000; Kutas et al. 2006; Federmeier 2007; Lau et al. 2008; Van Berkum 2009), the amplitude of the N400 reflects the computational resources used in retrieving the relatively invariant 'coded' meaning(s) stored in semantic long-term memory for the word at hand, with a more negative (bigger) N400 indicating a more costly retrieval process and a less negative (smaller) N400 reflecting less costly retrieval. Importantly, such retrieval always occurs in a specific context, and aspects of that context can predict or 'prime' the relevant meaning, such that retrieval becomes easier when the word comes along. So, combined with your knowledge about the world, *He buttered the bread with*… leads you to anticipate, say, *marmalade* or *peanut butter*, but not *socks* or *cars*. When the critical word then comes along, such predictions help retrieval of the former, but hinder that of the latter.

In the specific variant of this N400 model that I've recently argued for elsewhere (the Multiple-cause Intensified Retrieval account, Van Berkum 2009), a wide variety of information sources can give rise to expectations against which the next word comes in, including (a) associatively or semantically related prime words, (b) scenario-based knowledge about the world activated by (one or more words in) the preceding text, (c) a mental representation of the sensory context, e.g., visual or auditory scene, (d) the coded and contextually enriched meaning – "what is said" – computed for the unfolding sentence heard so far, (e) the Gricean speaker meaning – "what is meant" – inferred for the unfolding sentence heard so far, (f) a mental model of the situation being discussed, and (g) some metalinguistic representation of the discourse, e.g., its genre and register, the interlocutors involved, and the goals being pursued. *All* of this can raise conceptual expectations or predictions that can be met by the next word to varying degrees, with a better fit giving a smaller N400.

The studies reviewed above are by no means the only ones demonstrating prediction in language comprehension, and clear evidence for anticipatory comprehension can also be found elsewhere (e.g., Altmann & Mirkovic 2009; Delong et al. 2005; De Ruiter et al. 2006; Kamide 2008; Federmeier 2007; Federmeier & Kutas 1999; Trueswell

& Tanenhaus 2005; Wicha et al. 2004; see Coulson & Lovett *this issue*, for a recent example involving context-based speech act anticipation). Readers and listeners don't just passively sit back and enjoy the show – they continuously predict what their interlocutor is going to say or talk about next.

2.3. Should pragmaticists care?

Is this of relevance to the enterprise of experimental pragmatics? Yes, I think it is. First of all, experimental pragmatics is about how people combine code and context to construct non-natural meaning. If context allows one to *anticipate* meaning and *predict* upcoming bits of code, this must surely be an important part of the language processing story. Of course, as argued more extensively elsewhere (Van Berkum *forthcoming*), we'll need to flesh out what exactly is being anticipated (e.g., communicative 'moves', specific upcoming signs, developments in the world under discussion), via which mechanisms (cost-free memory retrieval, more effortful forward modelling of one's interlocutor, etc…), how predictions at one level percolate to another one (e.g., from a specific communicative move to a plausible upcoming word), and whether there is any deep distinction between predicting future states or current unknowns (compare *The next word will probably be X* to *One unmentioned but probably relevant feature of Y is Z*). But prediction does change the name of the game: if you can guess what's missing (in physical or conceptual space) and/or coming up (in time), your processing can to some extent run in 'verification mode'.

Second, the predictive nature of our brains seems clearly relevant to *specific* issues in pragmatics. Here are a few promising, sometimes even obvious candidates.

Turn-taking. Linguistic communication is a collaborative enterprise (Clark 1996; Tomasello 2008), and when people work together, they need to coordinate. To coordinate effectively, however, interlocutors have to anticipate what the other will do. In conversation, one clear example of this is turn-taking. On average, speakers around the world tend to start speaking within only a few hundred milliseconds after the end of their interlocutor's turn (Stivers et al. 2009; De Ruiter et al. 2006). Because the average gap between consecutive turns is a lot shorter than the average time needed to go from communicative intention to actual overt speech, speakers must prepare their turn before that of their interlocutor has ended. Under such circumstances, if you want to make sure that you start speaking when your interlocutor is done, you simply need to *predict* the end of his or her turn.

Stable patterns of coordination. Pragmatics has a rich history of finding and describing recurrent patterns of linguistic coordination. One is the *adjacency pair*, the systematic coupling of question and answer, offer and acceptance, or greeting and greeting (Levinson 1983; Schegloff & Sacks 1973). Conversation is strongly shaped by fine-grained expectations about what is and what is not a valid next move (Goffman 1981; Enfield 2009). *Genre* works in the same way, in that it raises fine-grained expectations about what is said when by whom and how (Steen *forthcoming*). Understanding how adjacency pairs and genres constrain real-time linguistic communication clearly requires thinking about predictive mechanisms.

Markedness-based inferencing. Speakers can exploit the comprehender's expectations for how things are typically expressed (in a particular sequence of moves, in a particular genre) by deliberately violating those predictions. The use of marked expressions (e.g., using *the blue cuboid block* instead of *the blue cube*, or describing a piece of art as *challenging* instead of just *good* or *bad*) is a fundamental way for speakers to guide the comprehender's search for interpretations. This idea is captured, for example, in Levinson's reanalysis of the Gricean maxims of conversation, notably heuristic 3 ("what is said in an abnormal way, isn't normal"; Levinson 2000). But for this to work in practice, people need to routinely predict the normal state of affairs, and do so effectively.

Context-dependent enrichment. In the debate on whether pragmatic enrichment requires 'dumb' but rapid default heuristics (e.g., Generalized Conversational Implicatures, Levinson 2000) or not (Wilson & Sperber 2004), one argument provided for such heuristics is that idiosyncratic context (e.g., the speaker's perspective, and what is in common ground) is deemed to be too rich and complex to rapidly help in fixing meaning. However, to the extent that our brains are great at having relevant enriching information ready at just the right time (possibly even in terms of what is in common ground and what is not), context-sensitive customized inferences about what the speaker intends to convey may not be so hard to draw (Van Berkum 2009). In this way, prediction directly bears on the debate.

The interpretive background. A related example concerns what is in the interpretive background as words come in. Formalisms such as DRT (Kamp & Reyle 1993; Geurts & Beaver 2007) have no trouble postulating, say, [$\underline{x}$; knight(x)] and [$\underline{y}$; dragon(y)] as explicitly introduced discourse entities in the domain under discussion. But of course, in terms of the *real* interpretive background those symbols are only the tip of the iceberg. For example, they also call to mind a fairy tale genre, specific event scenario's (often with a fair princess, some bold behavior by the knight, and a dead dragon in the end), and even specific concepts (e.g., sword, fire, courage, etc.) and words (such that the reader is less surprised at *slayed* than at *faxed*). The relatively inexpensive prediction afforded by long-term memory mechanisms in the brain may hold the key to the problem of how knowledge-rich information-processing systems tend to bring their vast background knowledge to bear on local processing, without clogging up.

These examples suggest that prediction, as a processing concept, is relevant to many specific issues in pragmatics. But there is also a somewhat deeper parallel between the central pragmatic question of how context and code interact in communication, and the theoretical neuroscience observations alluded to in the beginning of this paper. Remember that one important reason why neuroscience is moving towards predictive coding models of brain function is that, at least in visual perception, classic hierarchical bottom-up coding cannot deliver the speedy perceptions that real brains do – given the response speed of neurons and the complexity of the outside world, there simply isn't enough time to build things up from scratch (Mesulam 2008). This insight actually provides an interesting opposite to one of Levinson's arguments for code-based default heuristics (Generalized Conversational Implicatures, GCIs; Levinson 2000). In the classic computational frameworks of cognitive science, context-based computation is problematic, causing delays and combinatorial explosion. In such a framework, context-free code-based default heuristics can be assumed to speed things up. However, in at least some corners of the brain it's not the context that is causing delays, it's the context-free object-driven processing that is too slow – only with context can acceptable response times be achieved! If this also holds for language processing, rich context is not a barrier, but *the key* to speed.

Furthermore, if the raw environmental signal is just far too ambiguous and complex for the brain to deal with in a bottom-up fashion (Bar 2007; Friston 2005), and only *predictive* forward models allow us to segment, select and stabilize input so that we perceive stability and coherence in our environment (Bar 2007), this 'reverse processing' view may provide for a fresh perspective on the semantics-pragmatics interface. A classic and seductive idea about how semantic and pragmatic knowledge is brought to bear in actual language processing is that communicative meaning is first coarsely determined by the code (semantics), and then all remaining gaps are filled in by contextual factors (pragmatics). However, if the proximal input and/or the associated conceptual knowledge stored in long-term memory (i.e., the code) is really too ambiguous and complex to deliver stable representations, predictive context may well be essential to co-define (segment, stabilize) the code. Arguments about the fundamental indeterminacy of the code have already been made in pragmatics a long time ago (e.g., Clark 1996; Kempson 2001). But they now receive support from a perhaps unexpected corner: the neuroscience of perception.

Here's another take on this last point. To the extent that linguistic tokens simply instantiate a communicative move that was expected anyway, such as the uptake of an invitation, we will need to reconsider the classic idea that language comprehension proceeds 'upwards' through signal-driven semantic memory retrieval, semantic composition, contextual enrichment, and implicature recovery. After all, if we can already reasonably guess what the speaker meaning will be, information can flow the other way too. Also, if we have partial evidence that the currently unfolding move *is* an uptake (e.g., because somebody nods approvingly), this can constrain our perception of some of the linguistic signs used to realize the move, making sounds like *o*… or *ye*… more likely to be the onsets of *okay* and *yeah* than of *open* and *yesterday*.

Of course, guesses can go wrong, and new, unexpected things can be said. But that is not a sign of a fundamentally flawed architecture. In theoretical neuroscience, the concept of prediction error is now central to accounts of learning and attention allocation (e.g., Bar 2007; Friston 2005). And so it may be in language comprehension: it is only because we *expect* things that a particular message or its delivery is marked, and as such worthy of extra attention and additional inferencing. In other words: predictions are even useful when they are wrong.

Let me be clear: the claim is not that people working in the field of pragmatics have been totally oblivious to prediction – it is hard to think about adjacency pairs or genres, for example, without implicitly thinking about expectation, anticipation, prediction. But that's the point – these concepts are usually implicit. I think there is much to gain from considering their role in a more explicit way.

3. Valence

3.1. The brain cares about good and bad

As argued in the beginning of this paper, 'going neuro' can mean more than just using ERPs and fMRI, and talking about Brodmann areas. Importantly, it ideally also involves being guided by knowledge about what the brain is *for*, and how it achieves this goal. Well, the brain of *Homo Sapiens* is a fancy and highly flexible control system, evolved to make us more successful in negotiating a complex dynamic physical and social environment. Now, having eyes and legs and hands and stomachs is certainly useful too. But if you cannot use the visual information to make sensible decisions as to where to move and what to grab (or leave alone), you're not making the best of those facilities. That's where the brain as a control system comes in.

For a long time, cognitive scientists have viewed the brain as a knowledge-level system (Newell 1982), whose specialty was to compute accurate representations of the world, and store the invariant aspects of them in long-term memory for better future computation. Translated to psycholinguistics, this computer-inspired perspective has led scientists to for example ask how comprehenders construct a syntactic representation, derive a proposition, and update the situation model. In experimental pragmatics, we similarly ask how comprehenders use context to disambiguate word sense, compute reference, understand metaphorical expressions, derive conversational implicatures and compute other aspects of speaker meaning (see, e.g., the various papers in this special issue). It's all about knowledge, about how listeners work out the bits of information that speakers want to pass on to them, and about how speakers work out what listeners already know, so that a few less bits need to be transferred.

However, the brain is not a scientist analyzing the environment in a dispassionate way. Brains care about good and bad, about *valence*. And for good reason: staying away from bad stuff and approaching good stuff helps keep you alive, healthy, and attractive – and as such, it tends to help you generate offspring with the same useful inclinations. Special neural circuitry has evolved to handle valence in the brain, in a network that includes, amongst others, the amygdala, prefrontal cortex, the insula, cingulate cortex, the hypothalamus, nucleus accumbens, and the brainstem (see e.g., Cacioppo et al. 2004; Dalgleish 2004; Damasio 2004; Davidson & Irwin 1999; Dolan 2002; Ledoux 2000). This 'emotional brain' or 'affect system' – the term 'limbic system' has gone out of fashion – is central to making you feel good or bad about certain things, and to as such guide your behavior in accordance with the goals set by biological evolution and/or you as a goal-directed individual.

Because the stakes are high, parts of the affective system respond extremely rapidly to positive or negative stimuli, sometimes within a mere 100 to 150 ms (e.g., Grandjean & Scherer 2008; Pizzagalli et al. 2002; Schupp et al. 2004; Smith et al. 2003). And what makes these responses interesting to current concerns is that they feed back into the perceptual system, to enhance 'early' processing of the input in visual or auditory cortex ('emotional attention', Dolan 2002; Barrett & Bar 2009; Vuilleumier & Huang 2009). That is, what happens is that strongly valenced input very rapidly engages the affect system, which in turn boosts perceptual processing of those stimuli in relevant cortical areas, leading to stronger and – in terms of situation model updating as well as actual behavior – more impactful representations.

Valence is not just about heightened attention when we see something attractive, or hear a potential threat approach. Classically 'central' cognitive abilities like reasoning, judgement and decision making are also heavily influenced by the affect system (Dolan 2002; Damasio 1994; Gigerenzer 2007). According to the somatic marker hypothesis (Damasio 1994), for example, affective connotations made available by ventromedial prefrontal cortex are vital to decision-making, illustrated by the fact that people with lesions in this area are generally poor decision makers. The emerging idea in cognitive neuroscience is that the affect system is not just there to make us flee or fight, but to help us value – and hence reason adaptively with – information relative to our goals. In this perspective, rather than being framed as the irrational enemy of knowledge and reason, valence and the associated affect can be said to 'ignite' information that would otherwise be leaving us cold and motionless.

In addition to the effects of valence associated with specific input and specific ideas, there is good evidence that general background mood plays an important role in modulating the style of information processing (Ashby et al. 1999; Clore & Huntsinger 2007; Rowe et al. 2007). For example, in a bad mood people have a narrower focus of attention and they rely less on heuristics (scripts, social stereotypes, etc.) in reasoning and recall, whereas in a good mood their attentional focus tends to be broader and their reliance on heuristics goes up. The exact mechanisms at work here are heavily under debate, and sometimes related to the evolutionarily relevant regulation of exploratory behavior (e.g., Bar 2009b). But the phenomena are very clear: mood influences cognition in non-trivial ways.

Because of all these phenomena, but certainly also because of evolutionary concerns – the brain is there to keep its bearers alive in a dangerous world – attention in cognitive neuroscience is increasingly directed to the affect system and its interface with classic 'cold' cognition (e.g., the majority of talks and all four keynote speeches at a recent cognitive neuroscience meeting, the 49th Annual Meeting of the Society of Psychophysiological Research (SPR 2009) in Berlin, were about affect-related topics). As one neuroscientist has put it:

> Inclusion of work on emotion within the cognitive framework can help rescue this field from its sterile approach of the mind as an information-processing device that lacks goals, strivings, desires, fears, and hopes (LeDoux 2000: 157).

Equally important in the developing interest in how cognition relates to affect is the increasing realization that brain systems operate in a far less modular fashion than once assumed. In the words of another neuroscientist:

> The extensive structural and functional interconnectivity of brain parts indicate that no cell, cell assembly, area, region, or system is wholly autonomous. Purely language functions (if such exist), therefore, seem to be part of a much larger, apparently integrated system, and it may not be prudent to study them in isolation from perception, attention, memory, and action (Kutas 2006: 293).

3.2. Valence as part of meaning

So why should people interested in contextualized meaning care about all this? A first reason has to do with the grounding of lexical-semantic content in experience. There's a lot of talk these days about grounding symbol meaning. But whereas perception and action systems are usually seen as primary sources of 'semantic primitives', the *affective* system is not often considered as a useful ground. This seems unwise, for the core affective system is fully up and running – and a source of deep experience – at birth (and even before). This makes it an ideal candidate for the grounding of meaning.

The case is most obvious, but also most trivial, for emotion words (*joy*, *sadness*, *anger*): here, a true understanding of the meaning must simply be codetermined by personal affective experience. Because we all live in the same world and carry around roughly the same affect system, personal meanings constructed for these words will strongly overlap, to an extent that will make any semanticist happy. But what about the meaning of words like *euthanasia*, or *abortion*? Here, one's affective response may well differ radically, as a function of the moral-ethical environment in which one was raised, and the personal value system that emerged as a result. Hence, whereas the word *euthanasia* may well trigger a slightly negative affective response in a conservative Christian, the same word may elicit a (partly) more positive response in those who have come to associate it with compassion and elementary human rights. Is that part of the word's meaning for that person? Yes, I do not see why not.

We recently explored the processing of value-dependent meaning by recording EEG as respondents with opposing moral value systems filled out an opinion poll on morally relevant issues (Van Berkum et al. 2009). Critical statements were designed to be strongly consistent or inconsistent with the average moral value system of members of a relatively strict Dutch Christian party, referred to here as SC-group respondents. Examples (with the critical word in italics for expository purposes):

(3) I think euthanasia is an *acceptable* course of action.
(4) Watching TV to relax is *wrong* in my opinion.
(5) If my child were homosexual, I'd find this *easy* to accept.

We presented these statements to SC-group respondents and to non-Christian respondents with sufficiently contrasting moral value systems (NC-group), and asked them to indicate their agreement on a four-point *agree – disagree* scale. We measured EEG during initial reading only, before any response was given.

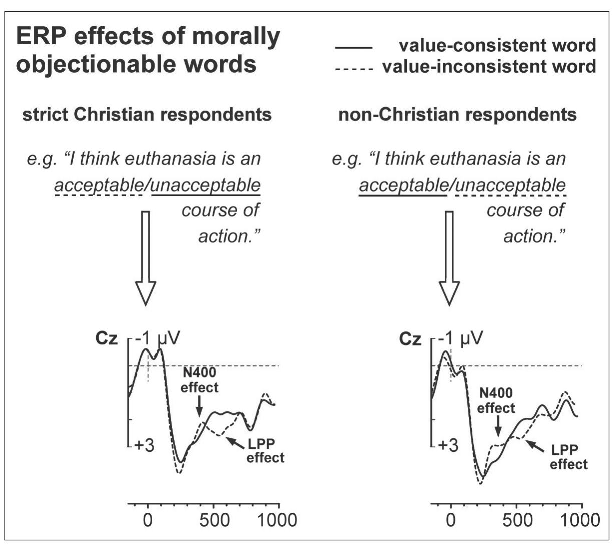

Figure 3. ERPs to value-consistent (solid line) and value-inconsistent (dotted line) critical words in opinion poll statements, for members of a relatively strict Dutch Christian party (left), as well as a non-religious control group with opposing moral value systems. Morally objectionable words are rapidly perceived as emotionally aversive (LPP effect) and affect the ongoing semantic analysis (N400 effect); the two effects partially overlap. Written word onset is at 0 ms.

As can be seen in Fig. 3, words where the unfolding compositional meaning of the statement began to clash with the reader's moral value system (e.g., for SC-group respondents, *I think euthanasia is an <u>acceptable</u>…*) elicited an immediate brain response, starting at 200 ms after the critical word.[2] Part of the neural response was an ERP effect commonly elicited by emotionally arousing stimuli (the so-called "Late Positive Potential"). The result of interest here, however, is that for both groups of respondents, morally offending words also elicited a small N400 effect, with a classic centroparietal maximum, and peaking at exactly 400 ms. This suggests that a person's values are not just brought to bear on language processing extremely rapidly, but that the associated affective evaluation actually *modulates* some aspect of the language-driven early semantic analysis itself.

Whether this bears on experimental pragmatics depends on how the subject matter of that field is defined. For one, doesn't the idiosyncratic nature of such value-dependent affective meaning simply remove it from the concerns of linguistics? In the context of a universal communication system, shouldn't we just be talking about universally shared aspects of meaning? Well, drawing the line around universally shared meaning is a legitimate way of defining one's object of study. Having said that, in the brains of actual language users, meaning is *always* idiosyncratically grounded in experience (even if it is the experience of words occurring in the context of other words, such as with learning about the world through definitions and novels). Hence, if you are interested in how the brain constructs context-dependent meaning, why leave value-dependent affective connotations of words like *euthanasia* or *abortion* out of the picture? For sure, such context-dependence may make communication a little harder. But that doesn't mean it's not real.

One could also point out that experimental pragmatics is about the construction of 'speaker' meaning, whereas these value-dependent effects seem to be about 'listener' meaning, the assumed downstream consequence of having successfully inferred speaker meaning. Again, this is in principle a legitimate way to carve up one's domain of study. But it does presume that listeners can objectively infer speaker meaning, without being in any way, at any given moment in processing, contaminated by their own perspective. In the domain of referential communication, such presumptions have been heavily debated (Keysar et al. 2003; Barr 2008; Hanna & Tanenhaus 2004), and the general answer seems that although people are very good at taking the other person's perspective into account, it is difficult to completely shut out ones own. More generally, one can ask whether the brain is really all that good in keeping its own needs and views crisply separate from those of others, at all times. Everyday experience, as well as recent scientific analyses (Marcus 2008; Gigerenzer 2007), simply suggest it isn't. Even our allegedly highly objective visual perception system – *I believe it when I see it* – appears to be contaminated by personal relevance right from the start (Barrett & Bar 2009). Pragmatics as a theoretical linguistic affair may be able to ignore that. But for experimental pragmaticists interested in actual processing, things may not be that easy.

The ERP study discussed above dealt with concepts such as abortion and euthanasia. Along with things like kindness and cruelty, they qualify as so-called "thick concepts" (Williams 1985), whose meaning has both a non-trivial descriptive and a non-trivial evaluative component. Of course, the interesting twist in the example study is that unlike kindness (which is presumably universally approved of), the evaluative component of something like euthanasia wildly differs across individuals, as a function of one's moral-ethical value system. But I suspect matters are even more complex, in that we're probably looking at a continuum where *every* concept can have an affective component to its meaning, with its nature and import depending on the specific person and situation. Take public speaking, computer, mortgage, skiing, or baby. None of these would qualify as traditional thick concepts. But, depending on the context, all of them can have mild or strong affective connotations that can be taken to be part of the meaning of the concept for us in that context. Because context-dependent affective connotations resist formal semantic analysis (but see Jackendoff 2007, for a useful framework), one can look upon this as epiphenomenal. However, the very same connotations often dictate our behavior, causing us to avoid or instead seek occasions where we can speak publicly, and to avoid or instead look for skiing and babies in our lives. If that isn't meaningful, then what is?

3.3. Valence and experimental pragmatics

Apart from valence being part of meaning anyway, there are other reasons why pragmaticists would do wise to at least consider valence and the affect system as relevant to their concerns. First, one can make a reasonable – if not by itself compelling – systems design argument, going like this: (a) All those fancy brain systems for perception, memory, decision and action are there to help us do the right thing; (b) language and the "interaction engine" upon which it rests (Levinson 2006; Tomasello 2008) is an evolutionarily recent *addendum* that greatly amplifies the power of this control system, by exploiting, reconfiguring, and possibly incrementing its older components with a discrete, extendable and transmissable scheme for conceptual and social coordination; (c) valence and affect are at the very heart of this control system, ‘igniting’ it with strong preferences and action tendencies and pervading all sorts of ‘cold’ representational processing (Barrett & Bar 2009; Damasio 1994; Dolan 2002; Vuilleumier & Huang 2009); and (d) hence, it makes sense to expect rich and interesting interconnections between the affective core of the control system and the communicative and linguistic systems that amplify its power.

Second, and consistent with this idea, language and communication *are* already clearly interfacing with valence and affect. As discussed in the previous section, one obvious way to ‘ignite’ cold representational processing is to have valence and other aspects of affect as proper components of meaning. Here, I want to draw attention to several other critical observations:

- Language use is *an instance of social interaction*, and the latter is simply drenched in valence and affect. We like people or we don’t, we happily or reluctantly engage in specific social interactions, and we carefully manage our social network. Such things also codetermine the pragmatics of language use. For example, speakers tailor the specificity of their referring expressions to mark social-affective relations (Enfield 2006). More generally, with each instance of language use requiring joint commitment to a common project at several levels (Clark 1996), the management of feelings about the project (e.g., face management) simply must be central to the endeavor. Moreover, according to Tomasello (2008), one of the three main goals of communication is simply to ‘share’, and to as such feel united and good together.
- Presumably related, language itself has an important extralexical ‘channel’ via which affective matters can be conveyed, regulated, and shared: prosody. Intonation can be used to express such attitudes as happy surprise, total disinterest, pride, compassion and defiance, and, in irony, it can even signal that the lexically conveyed meaning must be negated. Timing plays a critical role too. If you ask somebody whether he or she liked your presentation, for example, a long hesitation before the first word can say more than a million words. And then there are all these other ‘paralinguistic’ channels that co-define the communicative move: posture, facial expression, co-speech gesture. All these channels can do obvious work at the affective level, probably in part as additional signs with valenced contents

(i.e., like emotion words; see below), but probably also partly in a way that is more intricately intertwined with the very process of communication itself.

• Finally, a more specific observation pertaining to mood. Experimental pragmatics is interested in how people use idiosyncratic context and inferential heuristics to construct speaker meaning. Evidence from research on attention, memory, decision making, and social judgement that background mood can substantially modulate how the brain uses context and heuristics in information processing (Clore & Huntsinger 2007) is therefore directly relevant to the endeavor. In line with findings in these other domains, recent evidence from our lab (De Goede et al. 2009) suggests that whereas something like *David praised Linda because…* leads people to rapidly anticipate more information about Linda when they are in a good mood, a *sad* mood can completely abolish this type of heuristic anticipation. Interestingly, in the same study, syntactic parsing was unaffected by mood, showing that the mood-induced decline in heuristic anticipation is not caused by a simple failure to attend. In line with other results (Rowe et al. 2007), we suspect that mood affects the breadth of rapid semantic memory retrieval, regulating the degree to which more remote conceptual information can be brought to bear on real-time processing. It is not difficult to see that such a mechanism can greatly affect the context-sensitive processing that is central to pragmatic inferencing.

3.4. Multiple interfaces between language and valence

Based on considerations about what the brain is for, as well as on several other observations, I have argued that valence and the affect system should be of central interest to experimental pragmatics. However, I think it would be wrong to assume that there is a single interface to be studied. As we've seen, affect plays a role in communicative contents as well as in the mechanisms of communication itself, and this is most likely not a unified phenomenon. The influence of mood on heuristic inferencing brings in a third angle: 'incidental' affective factors that have nothing to do with contents or the joint communicative project can nevertheless modulate the processes that support context-dependent communication, via how they modulate basic brain functions relevant to a whole range of cognitive domains.

And it is not just the multifaceted nature of the language and communication system that makes things complex – the apparently simple concept of valence hides considerable complexity too. For one, valence is not a unidimensional phenomenon, as partly different neural systems deal with good and bad (cf., Cacioppo et al. 2004; Davidson & Irwin 1999; Dolan 2002), in sometimes orthogonal ways. Furthermore, valence itself is just one aspect of our affect system, a system capable of generating highly complex emotions. So, although the language system and the affect system can at some level be described as single systems, each has considerable internal complexity, allowing for multiple points (and different types) of contact between the two.

4. Conclusions

Experimental pragmatics asks how people construct contextualized meaning in communication. The central message of this paper is that if experimental pragmatics 'goes neuro', it should at least occasionally go beyond the instrumental use of EEG or fMRI, as well as beyond the modestly ontological neuro- approach that involves mapping classic theoretical distinctions onto Brodmann areas. Understandably, the experimental pragmaticist's view on processing has been heavily shaped by how, over the last few decades, cognitive psychologists and cognition-minded philosophers have tended to view the mind: as an information-processing machine that uses each bit of input, as it arrives, to piece together accurate mental representations of the environment (for downstream affect and further action, of course). But if we take a deep ontological 'neuro' perspective and ask about general principles of brain functioning in the light of what the brain is for, what seems immediately relevant here is that the brain evolved as a control system that helps its bearer negotiate a highly complex, rapidly changing and often not so friendly environment. In this environment, the ability to predict current unknowns, and to rapidly tell good from bad, are *essential* ingredients of processing – without it, we'd all be dead. Now, pragmaticists are not going to die if they ignore the pragmatics of the brain in their accounts of how contextualized meaning is constructed. But they are going to miss out on something vital. If the brain is a continuously highly proactive and strongly valence-controlled system, it may not be wise to treat it as a dispassionate scientist reactively puzzling over what it all means.

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Notes

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[1] The difference between a modest and a fully ontological neuro- approach is to some extent a matter of degree. However, as individual scientists, projects, or subfields gradually move from simply mapping classic cognitive science theories onto Brodmann areas towards thinking more deeply about the nature of the brain, something important does change along the way: rather than viewing the brain as the physical device upon which the theory must be projected (a remnant of the 'mere neural implementation' perspective), the brain is viewed as the device that the theory is about.

[2] We did not focus on the immediate response to words like *euthanasia* or *homosexual* for two reasons. One is a practical one: whereas ERP analysis requires a single focused critical word, most of our statements depended on complex concepts whose specification was distributed across a number of words (e.g., *Watching TV to relax*, or *The increasing emancipation of women*). The second and deeper reason was that we were interested in how value systems affected the construction of compositional meaning. Measuring ERPs at evaluative words like *acceptable*, *wrong* or *easy*, whose semantic contribution critically depends on the unfolding statement meaning, was thus more appropriate.

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