Towards a complete multiple-mechanism account of predictive language processing

Nivedita Mani[a] and Falk Huettig[b,c]

[a]Language Acquisition Junior Research Group, Georg-August-Universität Göttingen, 37073 Göttingen, Germany; [b]Max Planck Institute for Psycholinguistics, 6500 AH Nijmegen, The Netherlands; [c]Donders Institute for Brain, Cognition, and Behaviour, Radboud University Nijmegen, Nijmegen, The Netherlands.
nmani@gwdg.de   falk.huettig@mpi.nl

Abstract: Although we agree with Pickering & Garrod (P&G) that prediction-by-simulation and prediction-by-association are important mechanisms of anticipatory language processing, this commentary suggests that they: (1) overlook other potential mechanisms that might underlie prediction in language processing, (2) overestimate the importance of prediction-by-association in early childhood, and (3) underestimate the complexity and significance of several factors that might mediate prediction during language processing.

Pickering & Garrod (P&G) propose a model of language processing that blends production and comprehension mechanisms in such a way as to allow language users to covertly predict upcoming linguistic input. They ascribe a central role to our production system covertly anticipating what the other person (or oneself) might be likely to say in a particular situation (prediction-by-simulation). A second prediction mechanism, they argue, is based on the probability of a word being uttered (given other input) in our experience of others' speech (prediction-by-association). We agree with P&G that prediction-by-simulation and prediction-by-association are important mechanisms of anticipatory language processing but believe that they overlook other (additional) potential mechanisms, overestimate the importance of prediction-by-association in early childhood, and underestimate the complexity and significance of several mediating factors.

Multiple mechanisms. If we consider predictive language processing to be any pre-activation of the representational content of upcoming words, then only multiple-mechanism accounts of prediction that are even more comprehensive than P&G's can account for the multifarious phenomena documented in the language processing literature to date. Schwanenflugel and Shoben (1985), for example, have argued that more featural restrictions of upcoming words are generated in advance of the input in high as opposed to low predictive contexts. These featural (e.g., semantic, syntactic) restrictions may then constrain what words are likely to come up. In other words, pre-activation of representational content is constrained by the featural restrictions generated in particular contexts (e.g., via spreading activation in a semantic network). Whereas such online generation of featural restrictions may be compatible with prediction-by-simulation (as P&G appear to point out), it is conceivable that such pre-activation can also happen independently of prediction-by simulation and thus constitutes a third anticipatory mechanism.

Predictive language processing may also make use of certain heuristics and biases (cf. Tversky & Kahneman 1973). Borrowing the availability heuristic from decision-making research, upcoming words may be pre-activated simply because of an availability bias (certain words/representations may be very frequent or have occurred very recently). The analogy to decision-making

research is not as far-fetched as one may think: Tversky and Kahneman introduced a simulation heuristic in the 1970s according to which people predict the likelihood of an upcoming event by how easy it is to simulate it. Other heuristics may well be worth exploring (in line with the affect heuristic, emotionally charged words, e.g., stupid, boring, may be predicted more rapidly). Our point is simply that predictive language processing is likely to be complex and may make use of a set of rather diverse mechanisms (with many yet unexplored).

Importance of prediction-by-simulation in development. P&G suggest that analysis of children's prediction abilities might throw light on the distinction between prediction-by-association and prediction-by-simulation and place stronger emphasis on prediction-by-association in young children: Prediction-by-association might play a more important role when listeners and speakers have little in common with each other, such as the case of children listening to adults' talking.

In a recent experiment examining 2-year-olds' prediction abilities, however, we found that, consistent with prediction-by-simulation, only toddlers in possession of a large *production* vocabulary are able to predict upcoming linguistic input in another speaker's utterance (Mani & Huettig 2012; see Melzer et al. 2012, for similar results in action perception). Furthermore, if, as P&G suggest, covert imitation is the driving force of prediction-by-simulation, then 18-month-olds are equipped with the cognitive pre-requisites for covert imitation: Covert imitation can modulate infants' eye gaze behaviour around a (linguistically relevant) visual scene (Mani & Plunkett 2010; Mani et al. 2012) similar to adults' behaviour (Huettig & McQueen 2007). Prediction-by-simulation may also be an important developmental mechanism to train the production system (Chang et al. 2006). In sum, prediction-by-simulation appears to be crucial even early in development, and hence prediction-by-association is not necessarily the simple prediction mechanism which dominates early childhood.

Mediating factors. Finally, there are many mediating factors (e.g., literacy, working memory capacity, cross-linguistic differences) involved in predictive language processing whose interaction with anticipatory mechanisms have been little explored and whose importance, we believe, has been vastly underestimated. Mishra et al. (2012), for instance, observed that Indian high literates, but not low literates, showed language-mediated anticipatory eye movements to concurrent target objects in a visual scene. Why literacy modulates anticipatory eye gaze remains to be resolved, though literacy-related differences in associations (including low-level word-to-word contingency statistics, McDonald & Shillcock, 2003), online generation of featural restrictions, and general processing speed are likely to be involved. Similarly, Federmeier et al. (2002) found that older adults are less likely to show prediction-related benefits during sentence processing with a strong suggestion that differences in working memory capacity underlie differences in predictive processing. The influence of such mediating factors may greatly depend on the situation language users find themselves in: Anticipatory eye gaze in the visual world, for instance, requires the building of online models allowing for visual objects to be linked to unfolding linguistic information, places, times, and each other. Working memory capacity may be particularly important for anticipatory processing during such language-vision interactions (Huettig & Janse 2012).

More work is also required with regard to the specific representations which are pre-activated in particular situations. Event-related potential studies have shown that even the grammatical gender (van Berkum et al. 2005), phonological form (DeLong et al. 2005), and visual form of the referents (Rommers et al. 2013) of upcoming words can be anticipated. Most of these studies, however, have used highly predictive "lead-in" sentences. It also remains to be seen to which extent these specific representations are activated in weakly and moderately predictive contexts. Last but not least, languages differ dramatically in all levels of linguistic organisation (Evans & Levinson 2009). These cross-linguistic differences are bound to have substantial impacts on the specifics (and degree) of anticipatory processing a particular language affords.

Future work could usefully explore the cognitive reality and relative importance of the potential mechanisms and mediating factors mentioned here. Even though Occam's razor may favour single-mechanism accounts, we conjecture that multiple-mechanism accounts are required to provide a complete picture of anticipatory language processing.