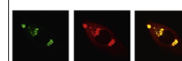


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Review

Four central questions about prediction in language processing

Falk Huettig^{a,b,*}^aMax Planck Institute for Psycholinguistics, P.O. Box 310, 6500 AH Nijmegen, The Netherlands^bDonders Institute for Brain, Cognition, and Behaviour, Radboud University, Nijmegen, The Netherlands

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ABSTRACT

The notion that prediction is a fundamental principle of human information processing has been en vogue over recent years. The investigation of language processing may be particularly illuminating for testing this claim. Linguists traditionally have argued prediction plays only a minor role during language understanding because of the vast possibilities available to the language user as each word is encountered. In the present review I consider four central questions of anticipatory language processing: Why (i.e. what is the function of prediction in language processing)? What (i.e. what are the cues used to predict up-coming linguistic information and what type of representations are predicted)? How (what mechanisms are involved in predictive language processing and what is the role of possible mediating factors such as working memory)? When (i.e. do individuals always predict up-coming input during language processing)? I propose that prediction occurs via a set of diverse PACS (production-, association-, combinatorial-, and simulation-based prediction) mechanisms which are minimally required for a comprehensive account of predictive language processing. Models of anticipatory language processing must be revised to take multiple mechanisms, mediating factors, and situational context into account. Finally, I conjecture that the evidence considered here is consistent with the notion that prediction is an important aspect but not a fundamental principle of language processing.

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*Correspondence address: Max Planck Institute for Psycholinguistics, P.O. Box 310, 6500 AH Nijmegen, The Netherlands.

E-mail address: falk.huettig@mpi.nl

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1. Introduction

The notion that prediction is a fundamental aspect of human information processing is not new and can be traced back as far as the writings of [von Helmholtz \(1860/1962\)](#) and [James \(1890\)](#). Over recent years however there has been a surge in the experimental study of prediction particularly in the fields devoted to the investigation of the relationship between perception and action. Many studies suggest that people predict the outcome of the actions of others as they unfold ([Sebanz and Knoblich, 2009](#)). Ensemble musicians for instance generate online predictions by simulating the concurrent productions of their co-musicians ([Keller and Koch, 2008](#); [Wolpert et al., 2003](#)). Knowing the task of a co-actor appears to influence one's own planning and performance even in situations that do not require taking the other's task into account ([Sebanz et al., 2003, 2005](#)). Mere knowledge of another person's upcoming hand movements activates our own motor systems even when no actual movement is seen ([Kilner et al., 2004](#)). Motor activation has also been observed when individuals use visual cues to prepare their own actions as well as when they use the same cues to predict someone else's actions ([Ramnani and Miall, 2004](#)). Similar results have been reported in developmental studies. Infants' motor development relies strongly on perception and knowledge of up-coming events ([Von Hofsten, 2004](#); see also [Hunnius and Bekkering \(2010\)](#)). Anticipatory eye movements have been reported in a great variety of real world tasks including tea-making ([Land et al., 1999](#)), sandwich-making ([Hayhoe et al., 2003](#)), driving ([Land and Lee, 1994](#)), and piano-playing ([Land and Furneaux, 1997](#)). This kind of predictive eye gaze is thought to support visuo-motor coordination ([Mennie et al., 2007](#)).

Experimental evidence such as this has led to the development of increasingly optimistic theoretical accounts of predictive processing. [Clark \(2013\)](#), see also [Friston \(2010\)](#) for instance suggests that prediction “offers a distinctive account of neural representation, neural computation, and the representation relation itself” and a “deeply unified account of perception, cognition, and action”. Clark even goes so far as to claim that “brains ... are essentially prediction machines”. The study of human language processing offers great opportunities to test such

claims. This is because linguists traditionally have been quite pessimistic about prediction being a fundamental influence on language processing. Prediction, many linguists argue, plays only a minor role during language understanding because of the vast possibilities available to the language user as each word is encountered. [Jackendoff \(2007\)](#), for example, has argued “predicting the next word has no bearing whatsoever on an explanation of speech production, where the goal has to be to produce the next word in an effort to say something meaningful”. “What good would such predictions do in understanding the sentences?” Jackendoff asks. Indeed, if prediction is a central characteristic of human cognition it should also be a central characteristic of human language processing.

Results of many psycholinguistic experiments however suggest that one reason why language processing tends to be so effortless, accurate, and efficient may be that mature (e.g., [DeLong et al., 2005](#); [Federmeier and Kutas, 1999](#); [Van Berkum et al., 2005](#); [Wicha et al., 2004](#)) and developing (e.g., [Borovsky et al., 2012](#); [Nation et al., 2003](#); [Mani and Huettig, 2012](#)) language users predict upcoming language input. Many psycholinguists therefore have proposed an important role for anticipatory language processing. [Federmeier and Kutas \(1999\)](#) conclude from their electrophysiological research “in the course of processing a sentence, the comprehension system is involved in some process tantamount to prediction”. [Pickering and Garrod \(2013\)](#) ascribe “a central role to prediction in language production, comprehension, and dialogue”. [Chang et al. \(2006\)](#) argue that “learning occurs because prediction occurs” and that therefore “syntactic abstractions arise from learners making tacit predictions”. Finally, [Altmann and Mirković \(2009\)](#) conclude that “prediction across time is key to the emergence of event structure” and that “most likely, therefore, prediction has a neural basis that pervades cortical function”. To evaluate such claims I believe it is useful to pose and answer four central questions about predictive language processing. Why (i.e. what is the function of prediction in language processing)? What (i.e. what are the cues used to predict up-coming linguistic information and what type of representations are predicted)? How (what mechanisms are involved in predictive language processing and what is the role of possible mediating factors such as working

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