ARTICLE IN PRESS

Journal of Experimental Child Psychology xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

The development of linguistic prediction: Predictions of sound and meaning in 2- to 5-year-olds

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ARTICLE INFO

Article history:
Received 6 December 2017
Revised 16 April 2018
Available online xxxx

Keywords:
Prediction
Sound
Meaning
Visual world
Learning
Eye movements

ABSTRACT

Language processing in adults is facilitated by an expert ability to generate detailed predictions about upcoming words. This may seem like an acquired skill, but some models of language acquisition assume that the ability to predict is a prerequisite for learning. This raises a question: Do children learn to predict, or do they predict to learn? We tested whether children, like adults, can generate expectations about not just the meanings of upcoming words but also their sounds, which would be critical for using prediction to learn about language. In two looking-while-listening experiments, we show that 2-year-olds can generate expectations about meaning based on a determiner (*Can you see one*. . .*ball/two*. . .*ice creams?*) but that even children as old as 5 years do not show an adult-like ability to predict the phonology of upcoming words based on a determiner (*Can you see a*. . .*ball/an*. . .*ice cream?*). Our results, therefore, suggest that the ability to generate detailed predictions is a late-acquired skill. We argue that prediction might not be the key mechanism driving children's learning, but that the ability to generate accurate semantic predictions may nevertheless have facilitative effects on language development.

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https://doi.org/10.1016/j.jecp.2018.04.012

Please cite this article in press as: Gambi, C., et al. The development of linguistic prediction: Predictions of sound and meaning in 2- to 5-year-olds. *Journal of Experimental Child Psychology* (2018), https://doi.org/10.1016/j.jecp.2018.04.012

Introduction

A growing body of evidence suggests that we can rapidly make sense of the world thanks to prediction (Bar, 2007; Friston, 2005; Pickering & Garrod, 2013). For example, we can process sentences faster when the grammar, meaning, and sounds of upcoming words are predictable (Huettig, 2015). But prediction may do more than facilitate our ability to process the world; it may also drive learning (Dell & Chang, 2014; Elman, 1990; Rabagliati, Gambi, & Pickering, 2016). Children might learn about language, for example, by comparing their naive expectations about upcoming words with the input and updating their linguistic knowledge when those expectations are incorrect (i.e., to minimize the resulting prediction error signal). Prediction, therefore, could serve to unify processing and learning.

According to one of the most influential formulations of these ideas, predictive coding (Friston, 2005, 2010), the mind is constantly engaged in an attempt "to match incoming sensory inputs with top-down expectations or predictions" (Clark, 2013, p. 181). Detailed sensory expectations are key to this process of prediction error minimization, and hence to learning, because they allow abstract predictions to be "grounded" in a format suitable for comparison with sensory input. But whereas there is good evidence that detailed predictions are part of the way in which adults process language, it is unknown whether children generate them and, if so, from what age. The aim of this study was to fill this gap. We tested whether children can generate predictions that are sufficiently detailed at the level of sounds that they give rise to informative error signals that may drive learning. This, of course, does not amount to testing whether such predictions do in fact drive learning in children, as expected under learning-via-prediction models, but we focused on testing an important precondition or assumption of such models—namely, that children can generate detailed sound predictions.

Detailed expectations about the forms of upcoming words—that is, more detailed than just their semantic meaning or syntactic category—can play a number of fundamental roles in learning. For example, they could help children to learn about relations between linguistic structure and linguistic form, including learning about irregularities. It has frequently been suggested that children might unlearn overregularizations (e.g., the plural of *mouse* is *mice,* not *mouses*) by predicting to hear one form (/maʊzɪz/) and, when they hear another form (/maɪs/), updating their internal representations (a suggestion known as implicit negative evidence; e.g., MacWhinney, 2004; Ramscar, Dye, & McCauley, 2013). This example also helps to illustrate how children may generate detailed predictions even as their knowledge is still incomplete (e.g., they know how to form regular plurals but not irregular plurals). Being able to specifically predict particular words and word forms could also be crucial for distributional learning; for example, a child who knows that *the robber* is more predictable than *the policeman* after *He will arrest* has learned something about the meaning and syntax of the verb *arrest* from its distributional properties (Elman, 1990; Gambi, Pickering, & Rabagliati, 2016). In this example, the child may leverage his or her emerging world knowledge (i.e., about the typical participants of arresting events) to generate detailed lexical predictions that help the child to learn about thematic and syntactic structure.

But although it is clear how low-level expectations about sound could drive language learning, there are reasons to believe that such detailed expectations may be too complex for young children to use. For instance, to be able to predict /maʊzɪz/, a child not only would need to possess a robust knowledge of the sound system, lexicon, and grammar of his or her native language but also would need to be able to quickly pass information between these different levels of representation in a top-down fashion. This second point is particularly important because a number of studies suggest that top-down processing may be slower or more limited in young children (e.g., Snedeker & Trueswell, 2004; Snedeker & Yuan, 2008), which would cause difficulty in generating detailed predictions. This, in fact, would be compatible with children's late unlearning of overregularizations (Marcus, 1995) and suggests that children may learn to predict rather than predict to learn.

Whereas children's ability to generate detailed predictions is unclear, there is good evidence that adults predict not only the meanings of upcoming words (e.g., Altmann & Kamide, 1999) but also their forms, including acoustic and orthographic properties (Dikker & Pylkkänen, 2013; Dikker, Rabagliati, Farmer, & Pylkkänen, 2010; Farmer, Brown, & Tanenhaus, 2013; Herrmann, Maess, Hasting, & Friederici, 2009; see also DeLong, Urbach, & Kutas, 2005; but see below). In an MEG study of reading,

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