

## Prediction supports infants' language processing and language development

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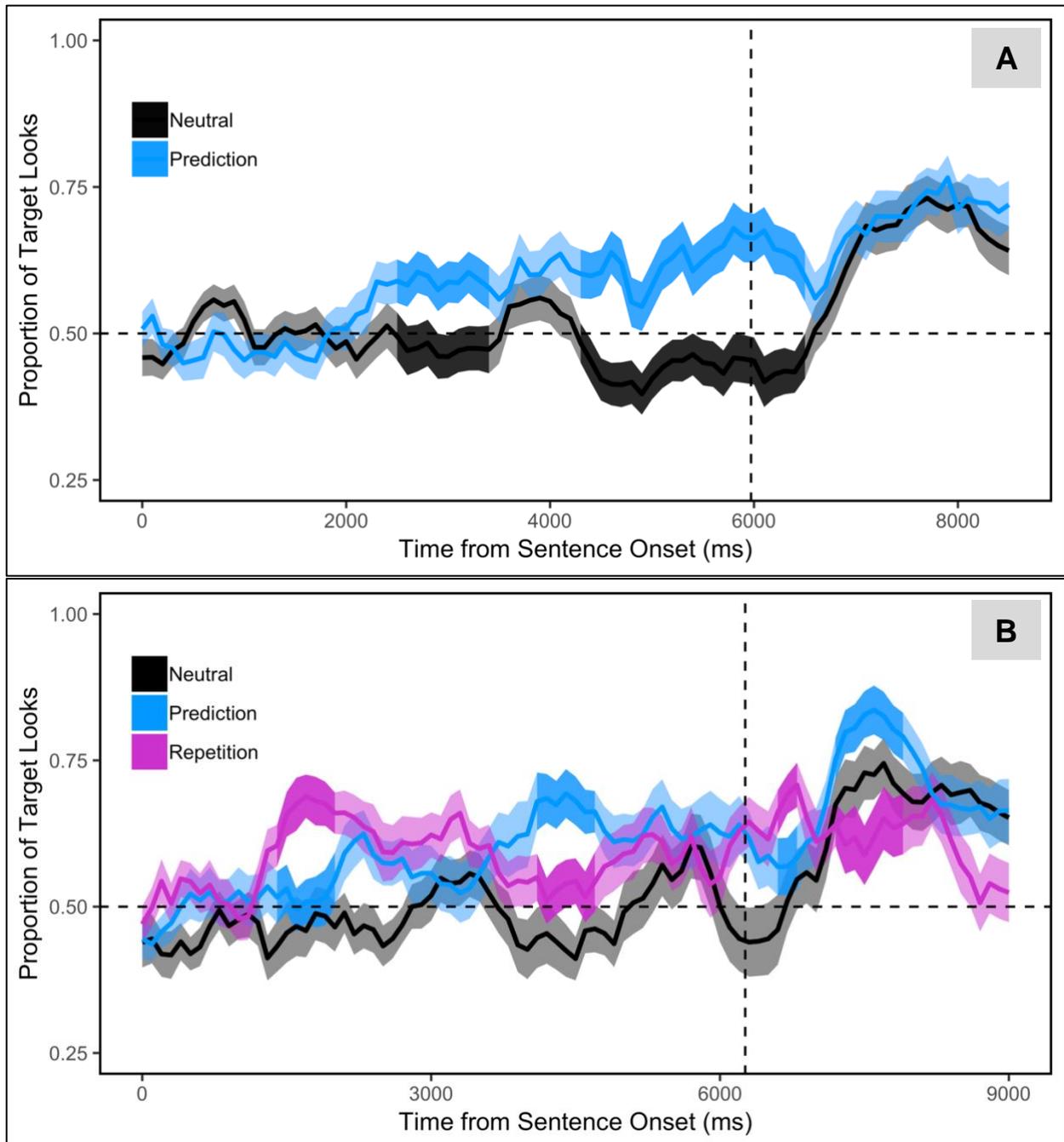
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Recent theories claim that **prediction** – the pre-activation of representations during processing – supports language development (Elman, 1990; Dell & Chang, 2014). A number of empirical findings support this view (Borovsky, Elman & Fernald, 2012; Lukyanenko & Fisher, 2016; Mani & Huettig, 2012; Reuter et al., 2018). However, prediction's role in development is debatable (Huettig, 2015). For example, while individual differences in prediction correlate positively with vocabulary size, the directionality is unclear: Prediction may be a cause or consequence of developmental changes (Rabagliati, Gambi & Pickering, 2016). Here, we present 2 eye-tracking experiments that contribute to this ongoing debate. Using a combination of group-level and individual-difference analyses, these experiments address limitations of prior research, evaluate the reproducibility of our findings, and further illuminate prediction's role in the early stages of language development.

In **experiment 1**, we evaluated infants' emerging abilities to predict and comprehend words from 12 to 24 months, when infants acquire hundreds of words (Fernald, Perfors & Marchman, 2006). Infants ( $N=67$ ; 12-24 months) viewed pairs of images (e.g., a ball and a cup) and heard trials with **prediction sentences** (e.g., *Let's go play! Bring a toy! It's fun to throw! Where's the ball? Find the ball!*) and trials with **neutral sentences** (e.g., *Look at that! There it is! Do you see it? Where's the ball? Find the ball!*). We analyzed infants' looks to the target image (e.g., ball) during sentences using cluster-based permutation tests (Maris & Oostenveld, 2007). We found that as soon as infants reliably comprehended a word (e.g., *ball*) at 15 months, they could also use related words (e.g., *play*) to predict it (Fig.1A). Individual-difference analyses revealed positive correlations between prediction and comprehension measures ( $r(63)=0.25$ ,  $p=0.045$ ) and between prediction and MCDI vocabulary percentile ( $r(59)=0.34$ ,  $p=0.007$ ). In sum, findings from Exp.1 – both at the group level and at the individual level – suggest that prediction emerges during early stages of word learning, that the development of prediction and comprehension abilities are tightly coupled, and that prediction supports language development.

In **experiment 2**, we aimed to replicate and extend our findings from Exp.1. We investigated whether infants' ability to predict a word was distinct from simply hearing the word. Is predicting *ball* from semantically-related words like *play* distinct from hearing the word *ball* itself? Infants ( $N=32$ ; 14-19 months) viewed pairs of images (as in Exp.1) and heard trials with **prediction sentences** and trials with **neutral sentences** (as in Exp.1), plus trials with **repetition sentences** (*Look at the ball! There's the ball! Do you see the ball? Where's the ball? Find the ball!*). Comparing prediction sentences and neutral sentences, we replicate our Exp.1 findings that infants can predict upcoming words ( $ps < 0.05$ ). Critically, we find that the behavioral dynamics of prediction are distinct from those of repetition (Fig.1B). Findings suggest that, during language processing, infants do not simply use related words (e.g., *play*, *toy*, *throw*) to activate a single, undifferentiated representation (e.g., *~ball*). Rather, infants appear to activate and pre-activate distinct lexical representations during real-time language processing.

In sum, we used a combination of group-level and individual-difference analyses to evaluate the developmental emergence of infants' language processing abilities. Findings suggest that prediction and comprehension emerge concurrently in infancy (Exp.1), that infants' prediction abilities correlate positively with their vocabulary size (Exp.1), and that prediction and comprehension are distinct language processing mechanisms (Exp.2). Furthermore, in an ongoing longitudinal study, we are evaluating whether infants' prediction abilities forecast their developmental outcomes 12 months later. Taken as a whole, the novel findings of these experiments contribute to an ongoing theoretical debate by suggesting that prediction supports both language processing and language development during the early stages of word learning.



**(A)** Experiment 1 infants' ( $N=67$ ) looks to target during prediction sentences (e.g., *Let's go play! Bring a toy! It's fun to throw! Where's the ball? Find the ball!*) and neutral sentences (e.g., *Look at that! There it is! Do you see it? Where's the ball? Find the ball!*). **(B)** Experiment 2 infants' ( $N=32$ ) looks to target during prediction sentences (as in Exp.1), neutral sentences (as in Exp.1) and repetition sentences (*Look at the ball! There's the ball! Do you see the ball? Where's the ball? Find the ball!*). **(A and B)** Horizontal dashed line indicates chance performance. Vertical dashed line indicates the onset of the target noun (e.g., *ball*). Line shading represents one standard error from the mean for each condition, averaged by subjects. Darker line shading represents a significant difference among conditions ( $p < 0.05$ ) and  $p$ -values from cluster-based permutation tests within 100-ms time-bins (Maris & Oostenveld, 2007).