

## Prediction and learning: A chicken-or-egg problem in language development

Prediction-based theories propose that prediction supports language learning (e.g., Christiansen & Chater, 2015). In line with this claim, children can generate predictions during language comprehension, and those who do predict tend to have larger vocabularies (Borovsky, Elman & Fernald, 2012). Yet the directionality of this relation is unclear: Does prediction support learning or does learning support prediction (Rabagliati, Gambi & Pickering, 2015)? We aimed to address this question by investigating the emergence of prediction and language comprehension across the second year of life.

We hypothesized that prediction and learning have simultaneous and bi-directional effects: Prediction supports learning, and vice-versa. If so, we expected to observe prediction and comprehension developing concurrently. Conversely, a certain level of comprehension expertise may be necessary for prediction (Rabagliati, Gambi & Pickering, 2015). If learning supports prediction, but not vice-versa, we expected to observe a time period wherein infants comprehend words, but do not yet generate predictions.

To evaluate these hypotheses, we tested infants ( $n=66$ ) cross-sectionally in four age groups: 12, 15, 18, and 24 months. In an eye-tracking task, infants viewed pairs of referents (e.g., cookie, shoe) and heard pre-recorded sentences (Table 1). Half of the sentences allowed infants to predict the target noun (e.g., *Let's go eat. Oh yum yum! Open your mouth! Where's the cookie? Find the cookie!*) and half were neutral (e.g., *Look at that! There it is! Do you see it? Where's the cookie? Find the cookie!*).

We recorded infants' looks to referents during each sentence, and analyzed their proportion of looks to the target referent (e.g., cookie). We operationalized prediction as target looks during the pre-noun time window (i.e., looking to the cookie while hearing '*Let's go eat...*') and operationalized comprehension as target looks during the post-noun time window (i.e., looking to the cookie after hearing its label).

We found 12-month-olds neither predicted nor comprehended target nouns. Target looks were at chance for both predictable and neutral trials during both time windows ( $p>0.05$ ). Fifteen-month-olds had marginally greater target looks for predictable trials pre-noun ( $p=0.09$ ) and target looks post-noun were above chance for predictable trials ( $p=0.04$ ) and at chance for neutral trials ( $p=0.40$ ). Eighteen-month-olds had greater target looks for predictable trials pre-noun ( $p=0.03$ ) and target looks post-noun were above chance for predictable trials ( $p=0.002$ ) and for neutral trials ( $p=0.04$ ). Finally, 24-month-olds had greater target looks for predictable trials pre-noun ( $p=0.009$ ) and target looks post-noun were above chance for predictable trials and for neutral trials ( $p<0.001$ ). Together, these findings reveal behavioral evidence for both prediction and comprehension in the early stages of language development (Fig.1).

In sum, we found that prediction and comprehension develop concurrently over the second year of life. As soon as infants comprehended words, they were also able to predict their identity using semantically-related words. This pattern of results suggests that relations between prediction and learning are simultaneous and bi-directional. This study provides developmental support for prediction-based theories and suggests that prediction supports language learning during – not after – the initial construction of language.

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Let's go <u>eat</u> . Oh <u>yum yum</u> ! Open your <u>mouth</u> ! Where's the <b>cookie</b> ? Find the <b>cookie</b> !
Let's take a <u>walk</u> . We need a <u>foot</u> ! We need a <u>sock</u> ! Where's the <b>shoe</b> ? Find the <b>shoe</b> !
Let's go <u>play</u> . Bring a <u>toy</u> . It's fun to <u>throw</u> ! Where's the <b>ball</b> ? Find the <b>ball</b> !
Let's have a <u>drink</u> . Have some <u>water</u> ! Have some <u>juice</u> ! Where's the <b>cup</b> ? Find the <b>cup</b> !

Table 1: Predictable sentences for each target noun (cookie, shoe, ball, cup).

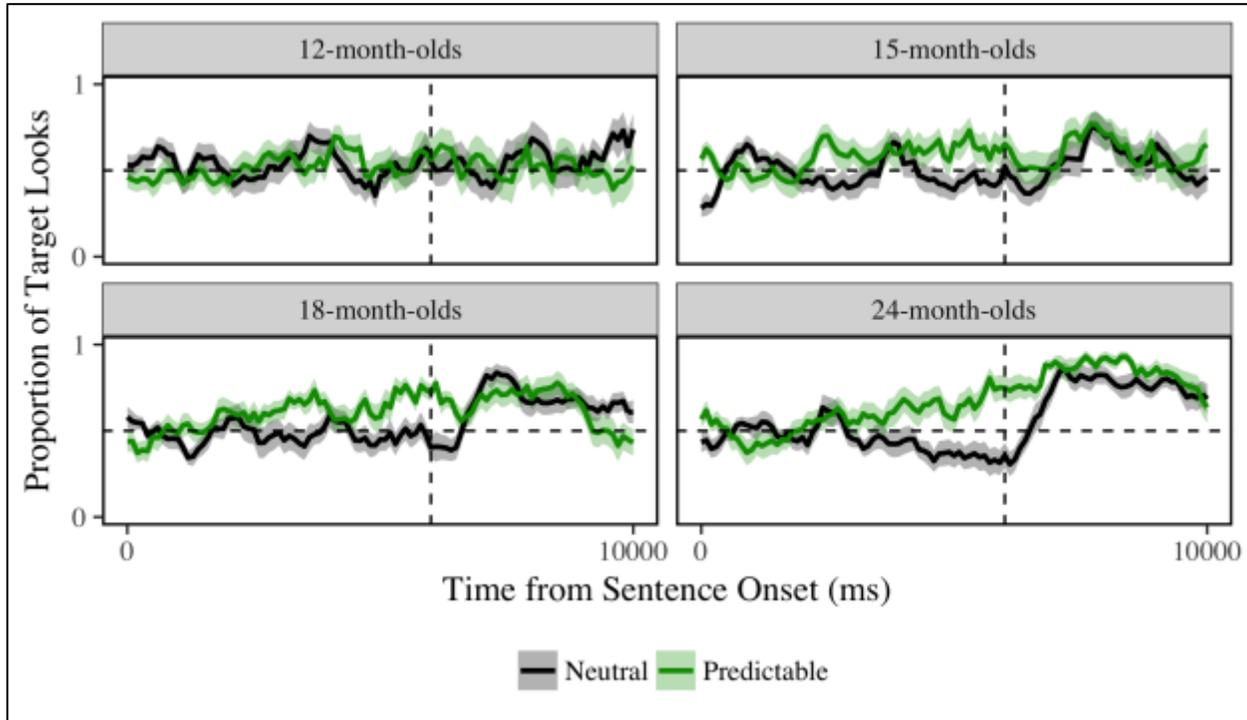


Figure 1: Proportion of looks to the target referent (e.g., cookie) during predictable sentences (green) and neutral sentences (grey). Horizontal dashed line indicates chance performance. Vertical dashed line indicates the onset of the target noun (e.g., cookie). Shading represents one standard error from the mean for each condition, averaged by subjects.