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A Model of Infant Preference Based on Prediction Error: How does motor development influence perception?

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Recent studies on infant action understanding emphasize a relation between action production and perception. Infants' ability to understand the goal of another person's action correlates with their ability to perform the action (e.g., Sommerville et al., 2008; Daum et al., 2010; Kanakogi & Itakura, 2011), and infants' preference for a motion exhibits a developmental change corresponding to their motor improvement (e.g., Sanefuji et al., 2008). However, the relation between action production and perception cannot be explained by a simple model. A closer analysis revealed that infants' preference for an action is observed only slightly before their action production (Hauf & Power, 2011). Once infants acquire the action, their preference disappears and is surpasses by another preference for an impossible but not random motion.

We suggest that a model based on a prediction error in sensorimotor coordination can reproduce this non-linear development. Our key idea is that external stimuli producing a moderate prediction error attract stronger attention of infants. Figure 1 illustrates the model to calculate a prediction error (cf., Blakemore et al., 1999). A forward model functions to predict a sensory feedback produced by a motor command, whereas a sensorimotor system provides an actual feedback generated by the motor input and/or external stimuli. With this model, infant motor development is considered as a process to learn the forward model by minimizing the prediction error through motor experiences. The more motor experiences infants have, the less prediction error the model produces.

We hypothesize that infants have a preference for stimuli producing a moderate prediction error, and therefore their preferred stimuli change with age because of their motor development. Figure 2 depicts a typical curve for motor development (left), where the prediction error decreases with an infant's age, and a preference function with respect to the prediction error (right). In the early stage of development, an infant only has an immature internal model for an action, which produces a larger prediction error (a-1). This makes the infant show a weak or no preference for the action (b-1) because the action is too difficult to understand. Then, the infant starts learning to execute the action by minimizing the prediction error (a-2). A smaller but not too small prediction error (i.e., a moderate prediction error) triggers a stronger interest in the action (b-2), which facilitates the infant's further learning. Finally, the prediction error gets close to zero when the infant acquires the internal model (a-3). The little prediction error diminishes the infant's interest in the action because it is completely predictable and does not need to be learned any more (b-3).

The course of development described above agrees with all findings in previous studies. Moreover, our model can explain a non-linear perception-production relationship in language development (Lewkowicz & Hansen-Tift, 2011), provide a consistent explanation for seemingly-contradictory evidences about infant familiarity/novelty preferences (Hunter & Ames, 1998; Houston-Price & Nakai, 2004), and predict the underlying mechanism for abnormal preferences in autism spectrum disorder (Happe & Frith, 2006). These potentials enhance the plausibility of our model.

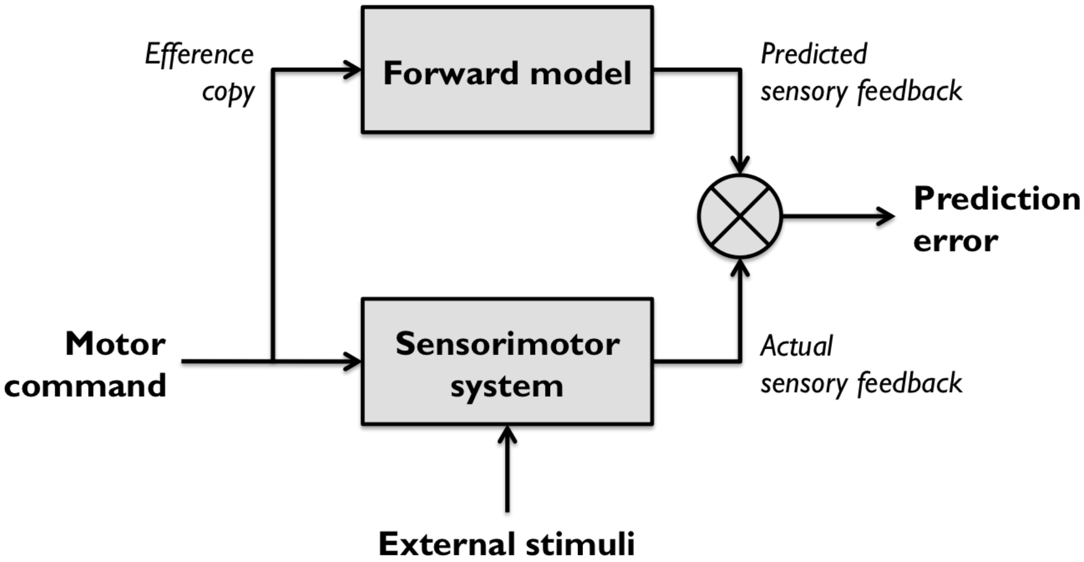

Figure 1: A model to calculate a prediction error. The forward model, which is learned through motor experiences, predicts a sensory feedback, whereas the sensorimotor system provides an actual sensory feedback generated by a motor command and/or external stimuli. The prediction error is calculated between them.

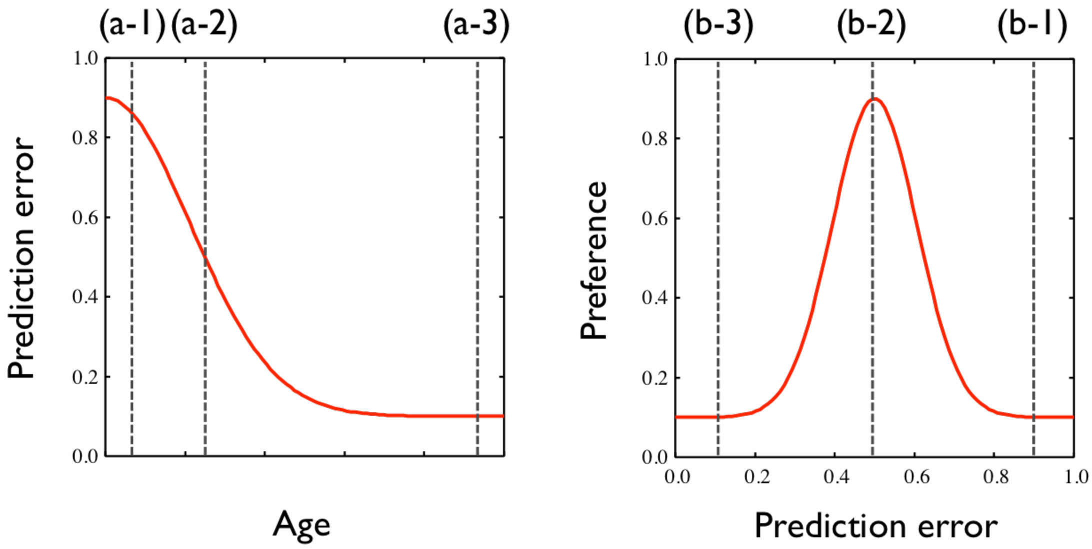

Figure 2: A typical curve for motor development (left) and a preference function with respect to a prediction error (right). An interaction between the motor development and the preference for a moderate prediction error produces non-linear development in action perception-production relationship.