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

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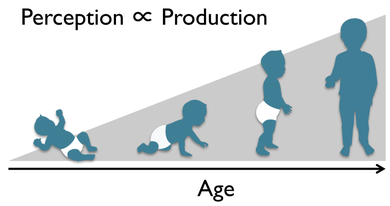
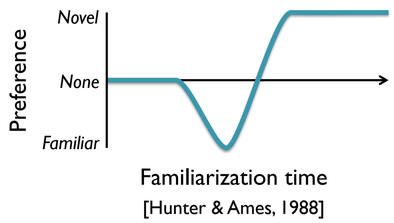
Research Motivation: Dynamical Change in Infant Visual Preference

- Correlation between action perception and production
  - Infants' ability to understand the goal of other person's action correlates with their ability to perform the action. [Sommerville et al., 2005; Daum et al., 2011; Kanakogi & Itakura, 2011]
  - Infants' preference for others' motion correlates with their motor ability. [Sanefuji et al., 2008; Hauf & Power, 2011; Hauf, 2013; Lewkowicz & Hansen-Tift, 2012]



- Familiarity vs. novelty preference

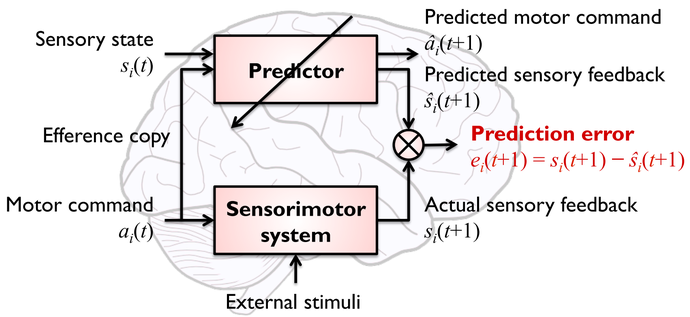
  Factors that influence infant preference:
  - Age: younger → familiar, older → novel [Hunt 1963; Wetherford & Cohen, 1973]
  - Familiarization time: shorter → familiar, longer → novel [Hunter et al., 1982; Hunter et al., 1983; Hunter & Ames, 1988; Rose et al., 1982; Roder et al., 2000]
  - Complexity of stimuli: complex → familiar, simple → novel [Hunter et al., 1983; Caron & Caron, 1968; 1969]
  - Affective reactions to stimuli: positive → familiar, neutral → novel [Nachman et al., 1986]

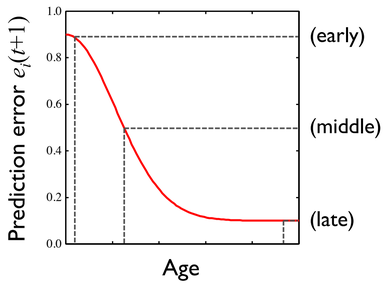


➔ **No consistent explanation about the underlying mechanism of infant visual preference**

Our Hypothesis: Prediction Error Determines Infant Preference

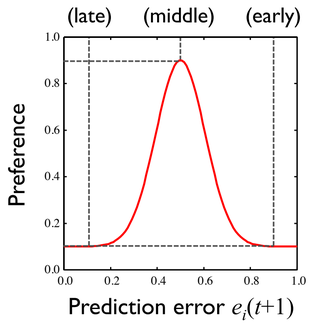
(1) Infants learn the predictor (the forward model) of the sensorimotor system through development.





(2) Infants have a fixed preference function: higher preference for a moderate prediction error, and lower preference for a smaller/larger prediction error.

(early) Large prediction error → Low preference (too difficult)
(middle) Moderate prediction error → High preference (learning)
(late) Small prediction error → Low preference (too easy)

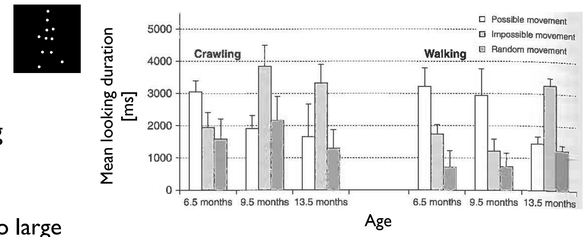


➔ **Infant preference changes with age because of the gradual decrease in the prediction error (i.e., sensorimotor development).**

Our Interpretation of Behavioral Studies

- **Preference for crawling & walking point light display (PLD)** [Hauf & Power, 2011; Hauf, 2013]
  - Visual stimuli: PLDs of crawling/walking adult
    a) Normal version
    b) Phase-shifted version (violated body constraint)
    c) Scrambled version (no body constraint)
  - Our interpretation: Infants prefer stimuli producing **moderate sensorimotor prediction error**.

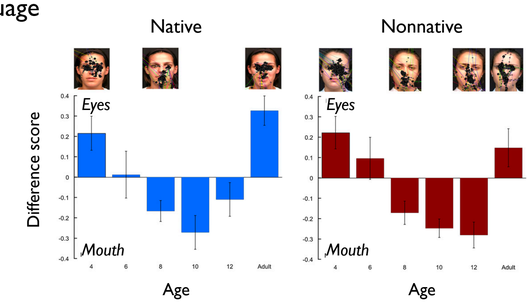
    e.g.) Prediction error of crawling stimuli:
    - Non-crawling infant (6.5 m): a = moderate, b = c = too large
    - Crawling infant (9.5 m & 13.5 m): a = too small, b = moderate, c = too large



[Hauf & Power, 2011]

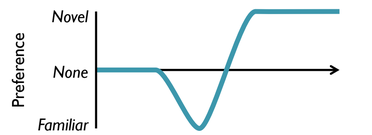
- **Preference for mouth of speaking person** [Lewkowicz & Hansen-Tift, 2012]
  - Audiovisual stimuli: Adult speaking native/nonnative language
    - Attention to mouth vs. eyes
  - Our interpretation: Infants look longer at the mouth when it produces **moderate sensorimotor prediction error**.
    - 4-8 m: mouth = too difficult
    - 10-12 m: mouth = moderate prediction error
    - Adult: mouth = too easy

    → Nonnative language increases prediction error about the mouth in older infants and thus induces attention shift to it.
    → Sound noise too. [Hisanaga et al., 2013 (in Japanese)]



[Lewkowicz & Hansen-Tift, 2012]

- **Familiarity vs. novelty preference**
  - Our interpretation: Infant **preference changes because of their prediction ability.**
    - Younger age / shorter familiarization / lower simplicity of stimuli: familiar = moderate prediction error, novel = too difficult
    - Older age / longer familiarization / higher simplicity of stimuli: familiar = too easy, novel = moderate prediction error



Adapted from [Hunter & Ames, 1988]

Conclusion and Discussion: Potentials of Prediction Error Hypothesis

- Dynamical change in **infant visual preference is modeled by sensorimotor prediction error**.
  - Infants seem to acquire various cognitive functions (e.g., self-other discrimination, imitation, altruistic behavior) through the minimization of prediction error. [Nagai, in press]
  - Visual preference based on prediction error enables infants to developmentally shift their attention from easy to difficult events with their age. → Maximizing learning progress [Schmidhuber, 1991; Vigorito & Barto, 2010; Oudeyer et al., 2007; Minato et al., 2010]
  - Different attention of ASD children [Pelphrey et al., 2002; Klin et al., 2002] and chimpanzees [Myowa et al., 2012] might be caused by their preference for more predictable events.

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