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Action Production Facilitates Action Perception through Sensorimotor Predictive Learning

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Developmental studies suggest that infants' ability to perceive others' actions correlates with their ability to produce the same actions. Kanakogi & Itakura (2011) revealed synchronized development of anticipatory perception of others' reaching and production of own reaching in infants. Sommerville et al. (2005) demonstrated that experiences of grasping an object enable infants to recognize the goal of others' grasping.

We propose a computational model to account for the underlying mechanism for this developmental link. Our model employs predictive learning of sensorimotor signals, which is considered as the basis for human cognition (Tani, 1996; Wolpert & Kawato, 1998; Rao and Ballard, 1999; Friston et al., 2006). Our key idea is that sensorimotor signals are learned integratively through own motor experiences and thus enable to mutually predict signals even if a part of the signals is unavailable (e.g., no motor signal during action observation). Fig. 1 illustrates the key idea. A robot first learns to predict visual, tactile, and motor signals while generating own actions (reaching for an object in our current experiment). The solid arrows in Fig. 1 represent the signal flow during the action execution. A sensorimotor predictor, which is modeled by an autoencoder, learns to integratively reproduce temporal sequences of the multimodal signals. Then, the predictor is applied to anticipate the goal of others' actions. When observing others reaching for an object, the robot receives only the visual signal while no motor or tactile signals are observed. Of importance here is that the predictor representing the integrated multimodal information enables the robot to recall the motor and tactile signals corresponding to the observable visual signal. Imaginary-produced signals can be then fed back to the predictor for further prediction (the dashed arrows in Fig. 1), which facilitates more accurate prediction of others' actions.

We replicated the experiment presented in (Kanakogi & Itakura, 2011) to verify our model. Bar graphs in Fig. 2 show the transition of accuracy of action prediction over learning. The dark blue, blue and light blue bars represent the percentage for correct prediction (i.e., the robot correctly anticipated the object other individuals were reaching for), incorrect prediction (i.e., it anticipated a different object to be reached for), and no prediction (i.e., it did not anticipate any object), respectively. The result demonstrates an improvement in the correct prediction synchronized with an increase in motor experiences. Significant differences between the correct and the incorrect/no prediction at the end of learning were observed only when the robot learned through action generation, but not through action observation. The line graph in Fig. 2 depicts the development of anticipation time (i.e., how fast the robot anticipated the object). It reproduces the developmental change observed in infants. We therefore conclude that our model based on sensorimotor predictive learning accounts for the underlying mechanism for the developmental link between action production and perception.

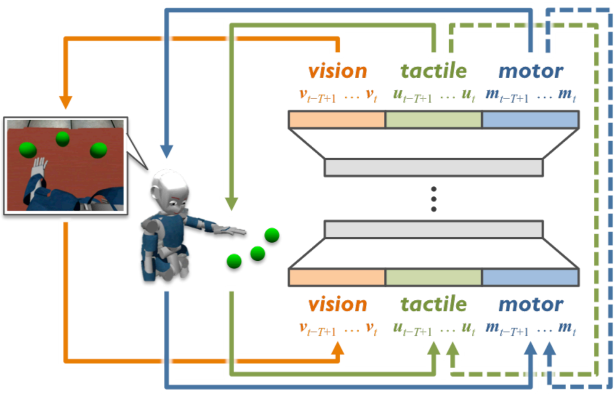

Fig. 1: A model of sensorimotor predictive learning accounting for the influence of action production on action perception

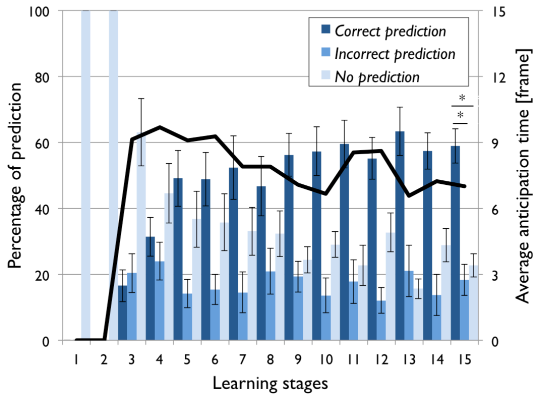

Fig. 2: Experimental results: the accuracy of prediction (bars) and the average time for goal prediction (line)