Emergence of stages for the development of body schemas

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Here at Aberystwyth University, we apply a strong developmental approach to learning sensory-motor control on an iCub robot. We use a mapping technique as a substrate to capture the sensory-motor and sensory-sensory relationships that are encountered in developing infants (and robots). As the maps become populated through experience so the robot displays stages in its behaviour. These stages are caused by constraints, such as immaturity in sensors or muscles, and we have experimented with schedules of constraint lifting in order to match the robot to the infant developmental timelines. The resulting collection of interconnected mappings built up through experience can be viewed as a distributed spatial body model [1].

However, the enforcement of explicit constraints on developmental stages may not be required. In a previous study of the developmental patterns in eye and neck sensorimotor coordination we demonstrated the presence of emergent constraints, requiring the eye control to be developed first before starting to learn neck control [2]. Not only this, but the study also suggested an optimal point at which a constraint on neck movement could be released in order to learn more efficiently. Extending this to incorporate a model of the sensorimotor control for the upper body, we can now model the developmental patterns and progressions observed in infants over the first 6-12 months [3]. As perceptual abilities such as visual acuity and sensitivity to different features change and improve, it is anticipated that further emergent stages will appear in the learning of sensorimotor control.

This model will allow further investigations into sensitive periods observed in infants [4]. The lack of key stimuli at critical points has been observed in human infants and animals to cause delayed or reduced competencies later in life. For example, visual or auditory impairments at birth with a longer delay in treatment result in reduced levels of acuity achievable later in life. Through varying the environmental stimulation and internal configurations on a robot, it is possible to study the effects of these on development in a way that is not possible with humans.

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[2] Shaw, P., Law, J. & Lee, M. An evaluation of environmental constraints for biologically constrained development of gaze control on an iCub robot. Paladyn 3, 147–155 (2012).

[3] Law, J., Shaw, P., Lee, M. & Sheldon, M. From Saccades to Grasping: A Model of Coordinated Reaching Through Simulated Development on a Humanoid Robot. Autonomous Mental Development, IEEE Transactions on 6(2), 93–109 (2014).

[4] Knudsen, E. I. Sensitive periods in the development of the brain and behavior. Journal of cognitive neuroscience 16(8), 1412–1425 (2004).