Development of eye-head gaze control on the iCub robot
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Introduction
A fundamental skill required in both humans and robots is the ability to direct gaze toward a target. Multiple body segments can be used to fixate a target, and here we describe our architecture for gaze control using eye and head movements and its implementation on an iCub robot.

Human gaze control is learnt in infancy and progresses through stages of development which are shaped by constraints on the infant. We describe how constraints are used to develop gaze control in our system, and how they impact on the learning process.

Gaze contributions
Eye and head contributions to gaze shift are generated separately. The eye moves the full distance to the target, whilst the head makes a smaller contribution based on the desired gaze displacement and initial eye position. Both movements are triggered almost simultaneously, but the eye reaches the target first and must counter-rotate to compensate for ongoing head movement.

Development in infancy
The poor visual ability and limited muscle tone of the neonate prevent eye-head gaze control at birth. Rather, the ability develops over time, in stages, as shown by our timeline of infant development [1]. Such stages are important to infant development, and provide useful lessons for robotics. We map the observed stages of development onto the sensor and motor modalities of the iCub. In particular we note that a lack of muscle tone prevents learning of neck control until eye control is sufficiently developed.

Results
We have experimented with the iCub learning eye-head coordination using both Type A and Type B constraints as shown below. Sequential results correspond to Type A constraints, using a threshold on saccade accuracy to trigger neck learning. Type B constraints emerge when eye and neck learning is allowed to occur synchronously but early, inaccurate, eye saccades prevent learning of correct neck movements.

Summary
The neural structure of the gaze control architecture suggests that accurate eye control is a prerequisite for learning the impact of head movements on gaze shifts: both eye and head movements are encoded separately, but eye reflexes prohibit learning head-only gaze shifts.

If both head and eye movements are learnt synchronously, correct head movements will not appear until saccades are sufficiently accurate: a Type B constraint. In infants, a lack of muscle tone limits neck movements, allowing the eye to reach well developed levels before neck control is learnt: a type A constraint.

Our gaze architecture enables very fast learning of gaze control on the iCub using both learning methods. Each has advantages, and we are continuing to investigate how both play a part in infant development.

References