Uppsala Babylab

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The predictive infant

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The necessity of predictive control

Adaptive behavior has to deal with the fact that events precede the feedback signals about them. In biological systems, the delays in the control pathways may be substantial. Furthermore, most events in the outside world require us to move to specific places at specific times while being prepared to do specific things. This entails foreseeing the ongoing stream of events in the world as well as the unfolding of our own actions.

The question is when and how such predictive control develops.

Modes of predictive control

A.Coordinating actions with external events

The movements must anticipate the external flow of events in order to coordinate with them.

B. Maintaining balance during action

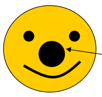
Anticipating one's own sway and perturbations of balance in order to maintain equilibrium.

C. Anticipation of action outcomes

Relies on a model of the action, its goal, and how to move there.

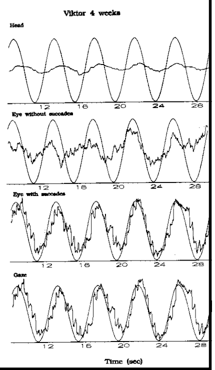
Development of smooth pursuit is a good example of how children at an early age come to coordinate their actions with external events. Smooth pursuit of an object, that changes speed and direction requires prediction of the upcoming object motion..

EOG was used to measure eye movements and reflective markers (**Qualisys**) to measure head movements. Gaze was obtained by adding eye and head movements.



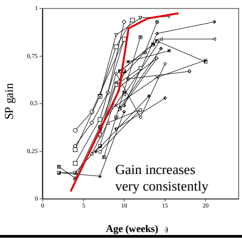
The nose of the target is a video camera

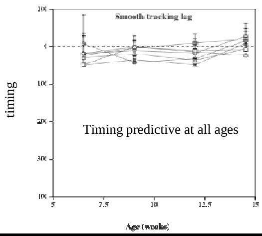
Object moves, infants stationary. In order to stabilize on the object, gaze should smoothly move with the object. This mode of control functions very poorly in this 4-week-old infant. In this example, head lags 600 ms and eye 300 ms. There are almost no smooth eye movements.



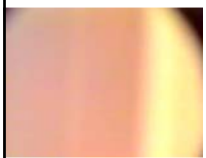
Observe that the object moves and the infant is stationary

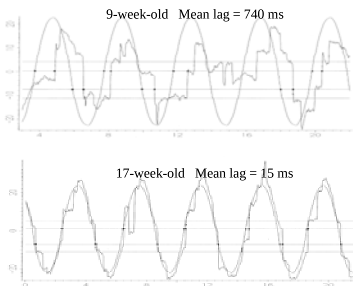
After this age, smooth pursuit eye tracking develops very rapidly. Already at 2 months of age, children track moving objects primarily with smooth eye movements. The increase in gain with age corresponds very well to the maturation of motion perception (red curve, Atkinson 2000)





If the object disappears temporarily behind an occluder, infants begin to anticipate its reappearance from around 4 months of age, suggesting that the predictive tracking is not just a mechanical sensori-motor coupling (Rosander & von Hofsten, 2004; von Hofsten, Kochukhova,Rosander, 2007)

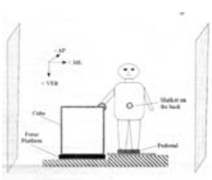


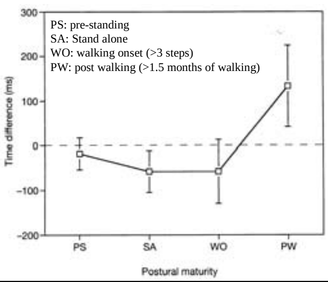


Maintaining postural stability during action is essential for efficient action.

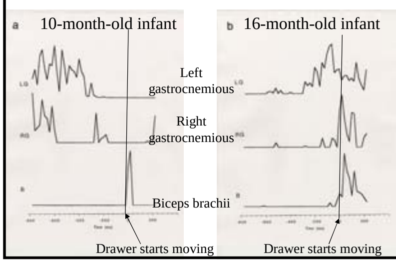
In order to maintain action continuity, threats to balance have to be compensated ahead of time. Such an predictive mode seems to develop in parallel with the the control of balance itself.

Barela Jeka & Clark (2000) measured the forces applied to a handrail when subjects were standing beside it.

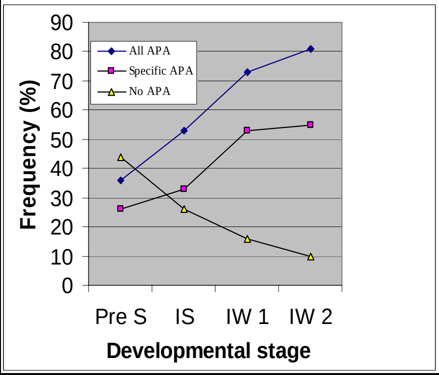




Witherington, von Hofsten, Rosander, Robinette, Woollacott, Bertenthal (2000) studied 10-17-month-old infants opening a drawer in a cupboard to take out a toy. The drawer resisted opening by a weight attached to it. To pull a drawer that resists pulling without loosing balance requires the subject to compensate for being pulled towards the cupboard.



We found that anticipatory control of balance is closely related to the mastering of independent standing and walking



Pre S =Prestanding

IS =Independent standing

IW 1= 2-12 weeks of independent walking.

IW 2 = 16 weeks or more of independent walking

All APA = recruitment of gastrocnemious <0.5 s before pull.

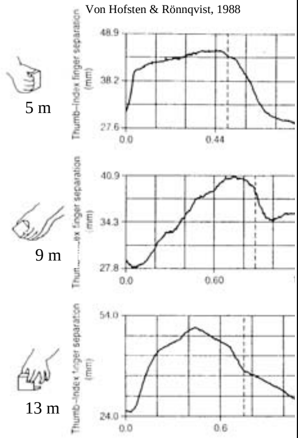
Specific APA = recruitment <0.25 s before pull

Prediction of action outcomes

From around 4 months of age infants reach for and grasp object appropriately. Several adjustments are then made ahead of time.

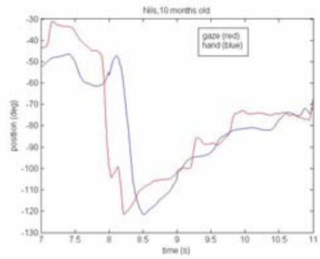
1. The hand open more for a large object than for a small one.
3. The hand configures itself in an appropriate opposition space to prepare grasping.
4. The hand closes around the object in anticipation of its encounter and not as a reaction to it.

Von Hofsten & Rönnqvist, 1988



When performing a manual action, infants look at the goal ahead of time. We studied 10-month-old infants and adults who displaced an object from one place to another. Gaze arrived to the goal, on the average, 0.48 s ahead of the hand for the infants and 0.38 s ahead of time for the adults.

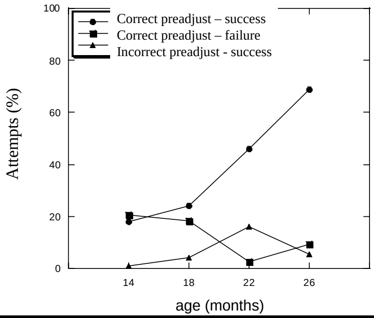
Gaze 300 ms before the hand to the goal



Prediction in the context of manipulation. We studied how 14-26-month-old infants inserted a single object into a snugly fitting hole. In half the cases, the object was lying down and in the rest it was standing up. The youngest infants were quite unsuccessful in all conditions, in spite of the fact that they tried very hard. The 14-month-olds were only able to insert the blocks in 20% of the trials and then mostly the cylinder and the square rod. 14- and 18-month-olds even failed in raising up objects that were presented lying down. When failing they often tried brute force. (Örnkloo & von Hofsten, 2007)

14-month-old infant, triangular rod

Only from 22 months of age, infants became systematically successful. They raised up the object and turned it appropriately ahead of time. This was the age when they began to systematically preadjust the object orientation both vertically and horizontally ahead of time.



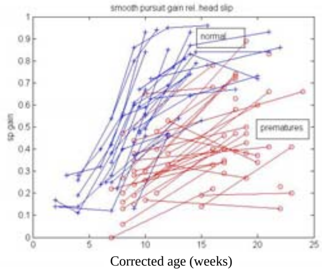
Predictive control is founded on knowledge about objects and events and the rules that makes actions and external events predictable. The examples of action development given above suggest that the acquisition predictive mode of control is a central part of action development.

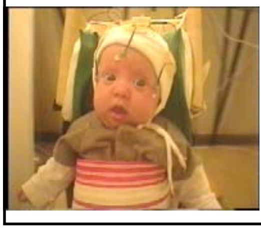
The ability to track objects smoothly and anticipate their reappearance after temporary occlusion is closely linked to the ability to perceive motion. The ability to compensate disturbances to balance in a predictive way is closely linked to the anticipation of body sway. The ability to manipulate objects in relational ways is linked to such abilities as mental rotation.

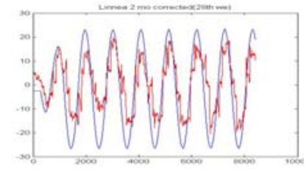
If prediction plays such an important role in motor development, one would expect that insufficient predictive control is a major determinant of motor disturbances.

Predictive control relies on perceptual as well as motor capabilities. Perceiving motion is one of the crucial components in such control. It may be damaged in very prematurely born, especially in infants born before week 32. The ascending pathways to the visual cortex are at risk, and especially the magnocellular ones carrying motion information. The condition is known as periventricular leucomalacia (PVL). The effects are persistent. For instance, Pavlova (2006) found that prematurely born teenagers with PVL showed impaired sensitivity to biological motion. Impaired motion perception will negatively affect all kinds of motor control especially the coordination with external events.

At present we are carrying out a study with over 100 children born before week 32. This sample constitutes 95% of these children born in Uppsala between 2004-2007. We have tested smooth pursuit at 2 and 4 months of age.







Perceptual impairments might not express themselves as directly in the implementation of actions as other neurological impairments, but they have wide and dramatic consequences for the functioning of the child. The treatment of perceptual dysfunctions are crucially dependent on their early diagnosis. Therefore we think that more effort should be devoted to the early identification of perceptual dysfunctions in infants.