Keeping the arm in the limelight: Advanced visual control of arm movements in neonates

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To test whether newborn babies have voluntary control over their limbs, spontaneous arm-waving movements were measured in the dark while the baby lay supine with its head turned to one side. A narrow beam of light was shone over the baby's nose or chest in such a way that the arm the baby was facing was only visible when the hand encountered the, otherwise, invisible beam of light. The results showed the babies were capable of precisely controlling the position, velocity, and deceleration of their arms so as to keep the hand visible in the light. The findings indicate that newborns can purposely control their arm movements to meet external demands and that the development of visual control of arm movement is underway soon after birth.

Keywords: Visual control of arm movement. Newborns.

Introduction

Traditionally, the emergence of successful reaching and grasping is described as a discrete step in development that suddenly emerges at around the age of 4 months. Newborn babies have long been thought to be reflexive creatures, responding to physical stimuli in a compulsory and stereotyped manner. However, research on prereaching1-3 and hand-mouth coordination4 suggests that spontaneous neonatal arm movements are, in fact, aimed and externally directed.

Recently, we recorded spontaneous arm-waving movements while newborns were allowed to see only the arm they were facing, only the opposite arm on a video monitor, or neither arm, while small weights pulled their arms away from their face in the direction of the toes. The babies opposed the perturbing force so as to keep an arm up and moving normally, but only when they could see the arm, either directly or on the video monitor.5,6 These findings suggest that newborns purposely move their hand to the extent that they will counteract the effect of weights pulling on their wrists so as to keep their hand in their field of view.

Successfully moving a limb or the whole body requires not only acting hand-in-hand with gravity and other external forces,7 but it also requires being able to adjust to environmental demands in a flexible manner. The perceptual systems, and notably vision, play an important role in the control of movement. Accurate control requires on-line regulation of muscular activation on the basis of perceptual information about the dynamics of the limb movement and the external force field, as well as about the movement of the limb relative to objects or surfaces to which it is being guided. Are neonates capable of using vision to precisely control their arm movements, or are the eye and the hand unconnected at birth as is commonly believed?

Method

To test whether newborn babies use vision in controlling their limbs, we measured spontaneous
Fig. 1. A newborn baby taking part in the experiment. Line drawing made from a photograph.

arm-waving movements while the baby lay supine facing to one side. Would manipulating where the baby sees the arm have an influence on where it holds the arm?

Subjects

Six full term, normal, newborn babies served as subjects, four girls and two boys, with gestational ages between 39 and 41 weeks and postnatal ages ranging from 10 to 24 days (mean = 19 days, standard deviation = 6 days). All deliveries were uncomplicated, vaginal births.

Apparatus and procedure

The infants were placed on their backs on a special baby bed tilted at about 20 degrees to the horizontal and were comfortably secured with a standard baby harness which allowed free movement of the head, arms, and legs. The infants spontaneously adopted a posture with the head to one side (see Fig. 1).

Infrared light emitting diodes (LEDs) were fastened onto soft bands around the baby's wrists. The LEDs were viewed by an overhead Selspot camera, with optical axis vertical, from a distance of 1.5 m. The x-axis in the camera's view was lined up perpendicular to the infant's body axis. The Selspot data were recorded on a computer at 62.5 frames per second.

The experiment was carried out under dim lighting conditions with a narrow beam of light (7 cm diameter) shining in one of two positions: high over the baby's nose (as in Fig. 1) or lower down over the baby's chest. The arm the baby was facing and which was only visible when the hand encountered the, otherwise, invisible beam of light, was called the seen hand; the opposite hand the baby was unable to see at all times was called the unseen hand.

Each infant was tested for a total of 6 minutes. The experiment comprised two blocks of six 30-second trials over which the two light positions were randomly distributed. During the experiment care was taken that the infants fulfilled the following behavioural state requirements. They had to be alert, with their eyes open, and be lying either quietly or making gross movements with the arms and legs (states 3 and 4 as described by Prechtl).

Results

Hand position data

The results indicate that the babies spent most of the 6 minutes recording time with their seen hand in the light. As a result, they held the seen hand significantly higher when the light was level with the nose than when it was level with the chest, whereas there was no such difference in wrist position for the unseen hand (repeated measures analysis of variance (ANOVA), F(1,5) = 7.79, p < 0.05).

Histograms of a typical newborn baby of the times the seen and the unseen hands were held up in relation to the position of the light are shown in Fig. 2. For the seen hand (Fig. 2a), two peaks can be seen corresponding to the position of the light.
Fig. 2. Times seen and unseen hands were held at distances above belly button in relation to the two positions of the light for a typical newborn baby. Lightly shaded area indicates light level with chest; darker shaded area indicates light level with nose. Note that the two light positions overlap slightly. For the seen hand (a), two clear peaks can be identified corresponding to the positions of the light. The wrist position of the unseen hand, however, appears to be normally distributed with no relation to the positions of the light (b).

**Hand velocity data**

Figure 3 shows wrist velocity plotted against its position for the seen and the unseen hands with the light positioned over the nose and chest for a
Fig. 3. Wrist velocity against its position for the seen (a, b) and unseen (c, d) hands with the light level with nose and chest for a typical newborn baby. The shaded areas correspond to the position of the light. For the seen hand, the high density of data points all concentrated around zero velocity in the shaded areas indicates that the baby changes the seen arm’s position and slows down its velocity to keep the hand illuminated and thus clearly visible. The unseen hand, in contrast, is kept largely stationary, and its position bears no relation to the location of the light.

Hand deceleration data

So far, the results show precise control of position and velocity of the wrist in the neonatal period. This raises the question: Would newborns also be able to control deceleration of the seen hand in such a precise manner? Figure 4 shows a typical position and velocity record of a newborn baby waving its arm. Every time a baby’s seen hand entered the light and remained there for 2 seconds or longer, the onset of deceleration (point of peak velocity) of the hand was noted with respect to the position of the light. Surprisingly, in 70 of all 95 cases (~74%) the babies started decelerating the arm before entering the light (as in Fig. 4), showing evidence of significantly more cases of anticipation of – rather than reaction to – the light ($t(5) = 3.7, p<0.01$). On those 25 occasions where the babies appeared not to anticipate the position of the light, 18 (~72%) occurred within the first 90 seconds of starting the experiment or changing the position of the light.
the light (see Fig. 5). This is clear evidence of both learning and memory in neonates. By waving their hand through the light in the early stages of the experiment the babies were learning about and remembering the position of the light. This very quickly allowed them to accurately and prospectively control the deceleration of the arm into the light and remain there, while effectively making the arm clearly visible.

**Discussion**

The results indicate that newborn babies purposely move their arm to the extent that they will change position and slow down the hand to keep the hand visible in a very limited area of only 7 cm across. This suggests sophisticated control of position, velocity, and deceleration of the hand rather than excited thrashing of the limbs, the way neonatal arm movements have been described in the past.9-11

These findings suggest that the spontaneous arm waving of neonates of the kind measured in our experiments is directed and under precise visual control. Neonatal arm movements are therefore not, as is commonly held, purposeless, but are in fact establishing early eye-hand coordination—a necessary precursor for effective reaching.12 Neonates can purposely control the position, velocity, and deceleration of their arms so as to keep them clearly visible. Their level of arm control, however, is not yet sufficiently developed that they can reach successfully for toys. Young babies have to do much practising over the first 4-5 months,13 after which they can even catch a fast-moving toy successfully.14,15

Our findings could have practical implications for blind babies16 and aid the early detection of brain damage in young babies. We are currently investigating whether preterm, low-birthweight babies who are neurologically at risk of developing perceptuomotor disorders such as dyspraxia ('clumsiness') and cerebral palsy show less sophisticated control of neonatal arm movements. Early identification of brain damage affecting posture and movement is important to allow the prompt start of intervention programmes which may have a beneficial effect on the developmental outcome of the child.17-19
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References


