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Topical Review

Eye-Hand-Mouth Coordination in the Human Newborn

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ABSTRACT

BACKGROUND: There have been several studies concerning rudimentary coordination of the eyes, hands, and mouth in the human newborn. The author attempted to clarify the ontogenetic significance of the coordination during the earliest period of human life through a systematic review. The neural mechanism underlying the coordination was also discussed based on the current knowledge of cognitive neuroscience. **METHODS:** Searches were conducted on PubMed and Google Scholar from their inception through March 2017. **RESULTS:** Studies have demonstrated that the coordination is a visually guided goal-directed motor behavior with intension and emotion. Current cognitive research has proved that feeding requires a large-scale neural network extending over several cortices. **CONCLUSION:** The eye-hand-mouth coordination in the newborn can be regarded as a precursor of subsequent self-feeding, and the coordination is very likely mediated through the underdeveloped but essentially the same network interconnecting cortices as in the adult.

Keywords: eye-hand-mouth coordination, cortical function, visuomortor circuits, feeding, newborn

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Introduction

For higher animals including humans, eye-hand-mouth coordination is essential for feeding and one of the most important motor integrations for life.[1] In humans, volitional eye-hand-mouth coordination to effectively attain a goal begins just before five months of age,[2,3] whereas there have been several studies concerning rudimentary coordination of the eyes, hands, and mouth in the newborn.[4-16] This review mainly concerns the ontogenetic significance of the coordination during the earliest period of human life but also discusses the neural mechanism underlying the coordination on the basis of the current knowledge of cognitive neuroscience.

Evolution of hand–mouth-associated movement in the human fetus

de Vries et al. found in their ultrasonic study of fetal movement patterns involving 12 healthy pregnant women that the onset of hand-face contact with rare insertion of fingers into the mouth occurs at 10 weeks' gestation.[17] Ianniruberto and Tajani discovered in their weekly ultrasonic study of fetal movements in 82 pregnancies from 8 to 41 weeks' gestation that the hands are frequently brought toward the head, face, and mouth at 12 to 13 weeks' gestation.[18] However, in these periods of gestation, the human motor cortex comprises only the first (deepest) pyramidal cell stratum, and most of the descending axons of the pyramidal neurons have not reached the white matter yet.[19] The hand-face and hand-mouth contacts in these periods are apparently not regulated by the cortices but are rather attributable to the pattern generator in the brainstem reticular formation that can produce intrinsically triggered spontaneous movements, and the reticulospinal pathways may carry the efferent signals.[20-25]

In the third trimester of pregnancy, the proportion of hand-mouth contact of the hand movements toward the face in the fetus increases.[26-29] Myowa-Yamakoshi and Takeshita found in their ultrasonic study of 27 fetuses between 19 and 35 weeks' gestation that direct hand-mouth contact was seen

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in 53 of the 106 observed episodes (50.0%) in which the fetuses moved the hand toward the face, and they also noted that the fetuses opened the mouth before the hand came into contact with the mouth.[27] Zoia et al. analyzed hand movements directed toward the mouth and eyes in eight fetuses serially at 14, 18, and 22 weeks' gestation and found that both at 14 and 18 weeks' gestation movements toward the mouth and eyes were very jerky, showing a kind of zigzag pattern, but at 22 weeks' gestation in each fetus the reaching became straighter and more directly aimed toward the target.[28] In their four-dimensional ultrasonic study, Reissland et al. assessed the longitudinal changes in hand movements toward the mouth and face in 15 healthy fetuses at 24, 28, 32, and 36 weeks' gestation.[29] They found that upper-face and side-face touching decreased, whereas lower-face and mouth-area touching increased with gestational age. The proportion of fetal mouth opening immediately preceding the arrival of the hand at the mouth area also significantly increased with age. Reissland et al. speculated that the increases in touching in the mouth area and anticipatory mouth opening with age are linked with fetal cortical maturation and preparation for feeding after birth.

These findings show that in the third trimester of pregnancy hand–mouth-associated movement in the fetus evolves from spontaneous purposeless movement into organized motor behavior directed to the goal of hand-mouth contact, which means that the control of the higher brain mechanism becomes dominant over the brainstem neural circuits toward birth.[19-23,30]

Eye-hand-mouth coordination in the human newborn

Hand-mouth coordination

Butterworth and Hopkins filmed the spontaneous motions in 15 full-term normal newborns (mean age: 79 hours) with a split-screen video system and analyzed the interrelation between hand, head, and mouth postures.[6] Their analysis showed that newborns could move the hand to the mouth either directly or indirectly through the perioral region of the face. The mouth opened in anticipation of arrival of the hand, which did not require visual guidance. They speculated that the hand-mouth coordination in the newborn is movement synergy proprioceptively organized by a central nervous mechanism formed before birth and stated that the coordination is not merely reflexive or impulsive but has all the characteristics of a goal-directed act and may be a developmental precursor of self-feeding. Lew and Butterworth assessed the hand-mouth coordination before and after feeding in 18 term newborns. They compared the proportion of mouth-opening before the hand contacted the mouth with that before the hand contacted the face both before and after feeding.[8] They found a significantly higher proportion of mouth-opening before contact to the mouth compared with that before contact to the face, before but not after feeding, and considered that these findings indicate a close link between hand-mouth coordination and feeding behavior in the newborn. Rochat also reported that following sucrose delivery, the proportion of hand-mouth contact clearly increased in comparison with hand-face contact, but when a rubber pacifier was inserted in the newborn's mouth immediately following sucrose delivery, upper limb movements toward the mouth dramatically decreased. It was concluded that hand-mouth coordination in the newborn is the earliest expression of a goal-directed action and an integral part of the feeding or sucking system.[7]

Eye-hand coordination

In a three-dimensional study involving two video cameras, von Hofsten analyzed the forward extension of the arm in 13 full-term newborns while they were presented with a visual target, which was slowly moved along a horizontal circular path, the nearest distance being 12 cm from the infant's eyes.[5] It was shown that the arm got significantly closer to the target when the subjects fixated the target than when they did not. He concluded that a rudimentary form of eye-hand coordination exists in the newborn, which constitutes a desirable foundation for subsequent development of coordinated motor behavior. In 15 infants between ten and 24 days old, van Der Meer et al. recorded arm-waving movements while the subjects lay supine facing one side with light-emitting diodes attached on their wrists with an overhead Selspot camera.[14] The subjects were allowed to see only the arm they were facing, or only the opposite arm on a video monitor, or neither arm. Small forces applied on their wrists pulled them in the direction of the toes. The infants opposed the perturbing force to keep the arm up and to allow it to move normally only on the side on which they could see the arm, either directly or on the video monitor. It was concluded that newborns can purposely control their arm movements in the face of external forces and that the development of visual control of arm movement gets underway soon after birth. Craighero et al. investigated 56 newborns with a preferential looking technique as to whether they were able to discriminate between visual cues indicating goal-directed and non–goal-directed actions.[16] Subjects were shown following eight actions on the video screen: the experimenter's hand approaches a ball (10 cm in diameter) and grasps it with whole-hand prehension; or approaches but the fingers are placed only in a pinch shape on the superior part of the ball without grasping; these videos are played back; and videos of these four actions are shown in which the ball is erased via software. The results demonstrated that the newborns oriented more frequently and looked longer at the hand shape with whole prehension than at the pinch shape, but only when the experimenter's hand reached the object. They also preferred to look at the hand being extended than being retracted, but only when an object was actually present. The authors concluded that newborns prefer a movement directed toward the external world only when it may develop into a purposeful movement.

Eye-mouth coordination

Futagi et al. first reported eye-mouth coordination in newborns, i.e., the infants opened the mouth as an examiner's index fingertip was directly approaching the mouth (Fig).[1] The fingertip was stopped for a moment just in front of the mouth without touching the lips and then retracted. Besides