

The Moro reaction: more than a reflex, a ritualized behavior of nonverbal communication

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Highlights

- We propose for the first time a phylogenetic meaning to the Moro reaction
- The gestures of the Moro have the characteristics of ritualization
- Ritualization transforms a physiological behavior to a communicative one
- The neural mechanism probably involves both the fear and separation-distress systems
- Parents should learn to respond to the Moro reaction by taking their newborn in their arms

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Abstract

Objective: To propose a hypothesis about the physiological meaning of the Moro reflex which remained difficult to understand since its publication in 1918 because both hands are free at the end of the gesture.

Method: According to the research methods in ethology, we selected a sequence that clearly showed the successive movements of the Moro reaction among the 75 videos of healthy term newborns we have filmed in a research project on antenatal education to parenthood.

Results: Microanalysis of the selected sequence showed the following succession of actions: quick extension-adduction of both arms, orientation of the body, head and eyes towards a human person, and full extension-abduction of both arms with spreading of the fingers, crying and a distressed face.

Discussion: The quick extension-adduction of both arms which started the sequence may be considered as a startle reflex controlled by the fear system. The Moro reaction following it has the characteristics of ritualization: amplitude, duration, stereotypy of the gestures. This evolutionary process turns a physiological behavior, grasping in this case, to a non-verbal communicative behavior whose meaning is a request to be picked up in the arms. Crying, orientation of the body, head, and eyes towards a human person are gestures of intention to communicate in support of our hypothesis. The neural mechanism of the Moro reaction probably involves both the fear and the separation-distress systems.

Conclusion: This paper proposes for the first time a phylogenetic meaning to the Moro reaction: a ritualized behavior of nonverbal communication. Antenatal education should teach parents to respond to the Moro behavior by taking their newborn in their arms with soothing words.

Keywords

Human newborn; Moro reflex; ritualization; nonverbal communication; active defense reaction; parental education

1. Introduction

In 1918, Moro described that if a baby is placed supine on a changing mat, and one hits both sides of the mat with one's hands, both arms jump apart symmetrically, then close in slightly tonic shaped arc movements, while both legs simultaneously show small movements. Similar arm movements were observed during head dropping in infants aged from a few hours to 3 months old in the supine position and was considered to be a labyrinthine reflex (Magnus & de Kleijn, 1912), in spontaneous awakening or after various stimuli such as changing diapers (Moro, 1918), when a sudden noise, hitting the abdomen, blowing a puff of air on the face, or applying hot or cold water on the abdomen (Freudenberg, 1921; Schaltenbrand, 1925). Spontaneous Moro reflexes were also observed during regular sleep (Wolff, 1959), and during the alerting exploratory phase after birth, more often in the supine than in the lateral position, and sometimes with enough force to fling the child's body from the supine to the lateral position (Desmond et al, 1963). Moro thought that this reflex was related to fear, but he did not understand that it was the inverse of any protection movement until he had read that human infants are breastfed mammals and need to be carried by their mother because they are not able to walk nor to support their own weight immediately after birth (Doflein, 1914). Taking into consideration that the reflex ended in a shaped arc movement, he proposed that it was an atavistic phenomenon and gave it the name of "*Umklammerungreflex*" (embracing or clasp reflex). To support his hypothesis, Moro drew a young orangutan to show how it clings to the body of his mother and pointed out that young human babies are continuously carried by their mother among peoples living in a primitive way, contrary to Western babies who are placed in cradles (Moro, 1918).

The clinical significance of the so-called Moro reflex received much attention. Moro reported that the reflex was more pronounced during the first weeks of life and disappeared after the third month, except in premature infants (Moro, 1918), and those with cerebral developmental disorders (Moro, 1920). Asymmetry of the reflex was found to be related to obstetrical damage of the brachial plexus or fracture of the clavicle (Gordon, 1929; Sandford, 1931). If the reflex is absent, reduced or hyperactive during the first three months of life, this may indicate various pathological conditions, mainly of cerebral origin (Zafeiriou, 2004; Dubowitz, Ricci & Mercuri, 2005), and its persistence beyond 6 months is significantly associated with Attention Deficit and Hyperactivity Disorder (ADHD) ($p = 0.0002$) in children aged 8 to 11 years (Koncarova & Bob, 2012).

The view that the Moro reflex was related to fear resulted in a long confusion with the startle reflex that can still be found in many websites, but they should be considered as two different clinical entities. The startle reflex is basically an immediate, fast, extension-adduction of the arms with eyes blinking in response to a stimulus, while the Moro reflex is a slower extension-abduction response of the arms (Hunt, Clarke & Hunt, 1936). The head-drop stimulus elicited more outward arm movements than inward arm movements ($p < 0.001$), while a sudden 96 dB noise stimulus elicited more inward than outward arm movements ($p = 0.011$) (Bench, Collyer, Langford & Toms, 1972). The respiration, heart rate, and transcutaneous pO₂ and pCO₂ autonomic parameters did not show significant alteration during Moro reflexes as they did in the startle reflex (Pucher, Haidmayer & Kenner, 1987). A very quick startle reaction can however precede the extension-abduction movement of the Moro reflex (Gordon, 1929; Hunt, Clarke & Hunt, 1936; Wieser, Domanowsky & Heinen, 1957; Prechtl, 1965).

The neural mechanism of the Moro response has also been a subject of discussion. The most usual stimulus to elicit the reflex is the head dropping method proposed by Magnus & de Kleijn (1912) and not the hitting of the changing mat on both sides of the baby's head as proposed by Moro (1918). Head dropping made it difficult to identify the location of the center of the Moro reflex and the neural afferent pathways because that method stimulates simultaneously the vestibular system and the proprioceptive receptors in the neck, both structures having afferent pathways to brainstem subcortical nuclei. The neural center of the Moro reflex seems to be located in the lower part of the brain stem because this reflex is present in anencephalic newborns (Karlsson, 1962, quoted by Prechtl, 1965; Katona 1998). Vestibular stimulation seems to play a crucial role in triggering the Moro reflex because it was obtained by fixing the head and body of the child on a table or a tilting chair to remove any proprioceptive stimulation of the muscles of the neck (Prechtl, 1965; Rönqvist, 1995), and, in anencephalic infants, it was only obtained when the vestibular nuclei were preserved (Hanabusa, 1975, quoted by Futagi, Toribe & Suzuki, 2012).

Several authors have tried to understand the phylogenetic significance of the Moro reflex. In human newborns, electromyographic recordings showed that this reflex was inhibited by the palmar reflex when traction is applied to both hands and that it is replaced by adduction arm movements with increasing clinging strength (Prechtl, 1965). In young monkeys clinging to their mother, sudden movement or sudden noise elicited an increase in the strength of clinging, which prevented falling (Hinde, 1961, personal communication quoted by Prechtl, 1965; Katona 1998). In young infants of a nomadic people living in the south of Botswana (Africa) who were worn naked, strapped tightly by a loincloth against the skin of their mother, Moro reflexes were observed at a loss of balance during feeding and ended in an adduction movement of the arms and clinging of one or both hands in their mother's breast or necklace. The survival value of this behavior would be to promote food intake by fixing the infant's mouth on the mother's breast (Konner 1972). The relationship between the Moro and palmar reflexes would be an argument in favor of a common evolutionary origin of both behaviors. The phylogenetic significance of the Moro reflex, however, remains difficult to understand

when it loses its physiological function when both the infant's hands are free (Prechtl 1965; Futagi, Toribe & Suzuki, 2012).

Reviewing the literature, we did not find any detailed study of the Moro reflex when it occurs spontaneously, that is to say without being caused by one of the usual stimuli: head dropping, knocking both hands on either side of the changing mat. When they occur spontaneously, the arm gestures described by Moro are no longer a reflex. They must be considered as a behavior which study falls within ethology, which was defined as the biological study of behavior in an attempt to answer the question: "*Why do these individuals behave as they do?*" (Tinbergen, 1963). Within 75 term birth videos previously recorded as part of a research project for prenatal parenting education, we observed several spontaneous behavior Moro reactions, often preceded by a startle reflex. The purpose of this paper is to present a hypothesis on the phylogenetic significance of the Moro reaction using ethology research methods in analyzing these videos.

2. Methods

2.1. Participants

Recruitment of participants to film the birth of their child was previously described. Written consent of both parents was obtained for using images or sequences from the videos for scientific and educational purposes (Rousseau et al, 2014).

2.2. Procedure

The steps of the research in ethology proposed by Tinbergen, one of the founders of the discipline, were: 1) selecting an observation underpinned by a hypothesis suggested by the observation of many instances of the behavior under study, 2) describing this observation in detail, 3) investigating the cause of the behavior, and 4) understanding its survival value (Tinbergen, 1963).

Identifying spontaneous Moro behaviors and selecting an observation for this study were made using the Edius Neo editing software (Grass Valley, USA) which allows frame by frame analysis of the videos, visualization of the sound intensity on the sound mixer display, and exportation of selected sequences. The video format used was the 25 frames per second European PAL. The description of the selected observation for this article was carried out using The Observer XT 12 software (Noldus Information Technology, Netherlands). The descriptive terms extension-adduction and extension-abduction were used to describe the newborn's arms gestures rather than startle or Moro reflex, which are interpretations and not observational facts. The Cohen Kappa test was used to check the data reliability between the two independent observers (PVR & FM/AW).

3. Results

A 14 second video clip which showed two successive bilateral arm extension behaviors in a human neonate was selected among numerous observations (Figure 1, photos 2 and 6). At the beginning of the sequence, a healthy male term newborn, aged 15 minutes, was lying

supine on a nursing table, eyes half open eyes, head turned towards his father who spoke to him softly, caressing his right arm with the left index finger (Photo 1). The two arm extension behaviors were separated by body tilting to the left, then to the right (Photos 3-4). The legs movements were not visible on the video.

The first arm extension behavior began at the moment of a sudden noise. The baby's head quickly turned toward the center line and the arms raised abruptly in extension-adduction with neutral face. At the acme of the movement, eyes blinked, arms were raised vertically, fingers were spread, hands were very close together, and the right hand was half flexed (Photo 2).

The second baby's behavior began after the father withdrew his finger and stopped talking. The baby turned to the left, forearms half flexed against the body (Photo 3). He then suddenly swung into his right side, grunting, arms half extended in adduction to the right, fingers spread with strong tremors. The face was neutral and the eyes were open (Photo 4). In this position, he issued increasingly powerful grunts "Uh, Uh, Uh" for about four seconds. Without any detectable stimulus, he began to cry very loudly, eyes closed in a distressed face, and raised the left arm progressively, then both arms in extension-abduction with disorderly movements (Photo 5). While the baby was crying, the mother softly called him by his first name and the father vocalized soft Tsk, Tsk, Tsk ..., but the baby was not soothed. At the acme of the movement, both arms were in full extension-abduction, hands open, fingers spread with fine tremor (Photo 6). Immediately after the acme of the abduction movement of both arms, the baby quickly brought both arms in adduction, turning towards his father, and started grunting again, his face in distress (Photo 7), and shouting until he was caught in the nurse's arms a few minutes later.

4. Discussion

4.1. Interpretation and meaning

The features of the first behavior of the video clip (Fig. 1, photo 2) were not those of the Moro reflex, but the ones of the startle reflex: appearing at a sudden noise, fast arm extension-adduction, eyes blinking, approximation of both hands, and absence of spread fingers at the acme of movement (Hunt, Clarke & Hunt, 1936). This reflex is controlled by the FEAR system which can be activated from birth by unconditioned stimuli such as sudden noise (Panksepp & Biven, 2012, p. 184). The capital letters are used to designate the primary emotional systems which control nuclei which are located in brain subcortical structures, and not to describe the emotion itself (Panksepp & Biven, 2012, p. XI). The arm adduction and the close proximity of the hands at the movement acme suggest that the startle reflex could be an attempt to cling, in the neonate at least.

The second behavior of the video clip (Fig.1, photos 3-6) was a full extension-abduction movement of both arms with spreading of the fingers, grunting, then shouting with a distressed face, after a double body tilting to the left then to the right. This behavior can be regarded as a true Moro reaction, because it is quite similar to the drawing by Moro himself in his original publication (Moro, 1918, Fig. 3).

The interpretation of the Moro reaction so far remained fruitless because the loss of any physiological function when the infant's both hands are free remained incomprehensible (Prechtl 1965; Futagi, Toribe & Suzuki, 2012). Careful observation of photo 6 (Figure 1) detected particular features that caught our attention: magnitude of the arm abduction-extension and fingers spreading, rigid posture at the acme of movement, and the stereotyped shape of the movement. These features are those of ritualization that is an evolutionary process of transforming a physiological behavior into a communication behavior whose purpose is to improve mutual understanding between individuals of the same species to prevent damaging conflicts and strengthen emotional bonds (Huxley, 1966; Eibl-Eibesfeldt, 1975, p. 213). According to Chalmers (1999), these observational facts led us to the assumption that in human newborns who cannot move nor support their own weight by clinging to their mother, the physiological behavior of grasping was transformed during evolution into a nonverbal communication behavior. Reviewing photos 3-5 (Figure 1), we detected other gestures before the Moro behavior: double body tilting, orientation of the head, eyes and body in the direction of an individual, the father in this case, vocalizations, and maintenance of these gestures for about 4 seconds (Figure 1, timeline and photo 4). These gestures are a further argument for considering the Moro reaction as a nonverbal communication behavior because they denote intention to communicate among human infants and young of species that belong to the same clade, bonobos and chimpanzees (Gillespie-Lynch, Greenfield, Feng, Savage-Rumbaugh & Lyn, 2013).

The hypothesis of the Moro behavior as an act of non-verbal communication cannot be accepted unless it meets several conditions. 1) The level of awareness of the newborn must be sufficient so that s/he is able to communicate with another human being. Experimental data have established that, from birth, the human newborn has an implicit scheme of a delimited, oriented, and located body, and that s/he is able to act in a multimodal fashion on his or her physical and human environment (Rochat, 2010). 2) People who perceive the behavior must understand the semantic content, the meaning of the message, and make an appropriate response. The father and mother responded only by soothing vocalizations to their baby's Moro behavior, but the nurse replied, taking him in her arms. 3) The behavior of the newborn must be affected by the answer given to him. The newborn showed distress signals when he received no answer and left in the supine position (Fig. 1, Photos 6 and 7), while he calmed down as soon he was held in the arms of the nurse.

The issue to address from a biological point of view is why this newborn behaved as he did (Tinbergen, 1963). The neural mechanism of the Moro reaction is less well known than that of the startle reflex that is triggered by a threat stimulus in the subcortical nuclei of the FEAR system (Panksepp & Biven, 2012) and modulated by cortical structures (Neuner et al., 2010). The neural center of the Moro reflex is also located in subcortical nuclei (Karlsson, 1962, quoted by Prechtl, 1965; Katona 1998), but its primary emotional control system has not so far been described. The FEAR system is probably not the only control center when the Moro behavior is carried out without any noticeable stimulus and when it follows gestures that indicate intention to communicate (Fig. 1, photos 3-6). The crying face of the newborn who did not receive any response suggests that it is the separation-distress or GRIEF/PANIC

system that is activated as it is in young animals separated from their mothers (Panksepp & Biven, 2012, pp. 313-316). Appeasement after taking in the arms showed that it was the adequate response to the Moro reaction. This maternal behavior is probably activated by the CARE system. It meets the primary need of attachment which is essential for infant survival and development (Bowlby, 1969). Moreover, it is significantly more effective than mother-talk alone to calm a crying newborn and to elicit the alert state which is necessary for its development (Thoman, Korner & Beason-Williams, 1977).

The hypothesis of an evolutionary transformation of a behavior that we are proposing for understanding the newborn's Moro reflex may also be applied to toddlers. When these children play close to their mother sitting on a chair, they regularly come in front of her, holding the arms up to be picked up (Anderson, 1972). The arm gestures of these toddlers suggest that the so-called primitive Moro reflex might not entirely disappear after the age of three months. It could continue to evolve towards a more conscious and comprehensive communication behavior during child development as does the evolution of the newborn's walking reflex through functional reorganization of neural circuits (Ivanenko et al. 2013). This hypothesis should be confirmed by future research.

4.2. Possible implications

The hypothesis of a ritualized behavior of nonverbal communication as interpretation and meaning of the Moro reaction may have implications for birth room routines and parental education.

Repeated stimulations of the FEAR system by unconditioned stimuli teach the animal or human individual to become frightened by environmental stimuli which are initially neutral, but become conditioned stimuli to a point of promoting the development of anxiety disorders (Panksepp & Biven, 2012). Further studies are needed to verify whether the systematic search of the Moro reflex by the usual stimuli could be replaced by careful observation of spontaneous, complete, and symmetric Moro behavior at birth or during neonatal care.

The mother's and father's unsuccessful attempts to stop their baby crying by soothing vocalizations may be due to their ignorance of the meaning of the Moro behavior or to the inhibition of their parental behavior by the rigidity of routines in Western maternity wards. Antenatal education should inform parents about the human newborn's abilities to communicate by gestures like Moro behavior so that they can reply adequately and reassure their child, which is one of its primary needs at birth (Bowlby, 1969). Obstetric unit professionals should learn to give more freedom to the spontaneity of parents during the first affective interactions with their newborn baby.

4.3. Strengths and weaknesses of the study

The strength of this ethological study is to propose for the first time an explanatory hypothesis to the Moro behavior which remained difficult to understand for nearly a century. This explanation involves two steps. First, the interpretation of observed facts is made by induction to scientific theories, namely the evolution of a functional act, clinging, to an act of

non-verbal communication through the process of ritualization. Second, the meaning is made by prediction of the semantic content, the meaning of the message, which is a request for being held in the arms of an adult as far as the Moro behavior is concerned (Chalmers, 1999).

The second interest of the study is to open areas for further research 1) to study the possibility of removing stimuli that would impair the child emotional development by the repeated triggering of the Moro reflex to check the integrity of the nervous system, and 2) to test the hypothesis of the evolution of this primitive non-verbal communication behavior towards a more elaborate behavior in toddlers.

This study could be criticized for the subjectivity that would have guided the selection of a single observation of the Moro behavior among the many others that we found among the 75 videos. The main criterion was the technical quality of the video that helped cutting the newborn's behavior into consecutive gestures (Figure 1, photos 2-7). In addition, frame by frame analysis of demonstration videos of the Moro reflex on the web shows the same sequence of actions as that of Figure 1: quick adduction of both arms, head turned towards the examiner, extension-abduction of both arms, spreading of the fingers, face in distress, and cries, unless the child had a pacifier in the mouth.

5. Conclusion

Moro's intuition that the behavior he described was inherited from evolution was quite outstanding at a time when the evolutionary process of ritualization was not known. He was probably right when he proposed that when this behavior occurred as a reflex, it was caused by fear. However, his interpretation does not seem complete because when the behavior occurs without any detectable stimulus, it could also be triggered by the GRIEF/PANIC system. In both situations, the distress expressions of the newborn who did not receive any response should stimulate the parents' CARE system. Antenatal education should prepare parents, primarily mothers, to soothe their newborns by taking them in their arms when they express their fear or distress by the Moro behavior.

Conflict of interest

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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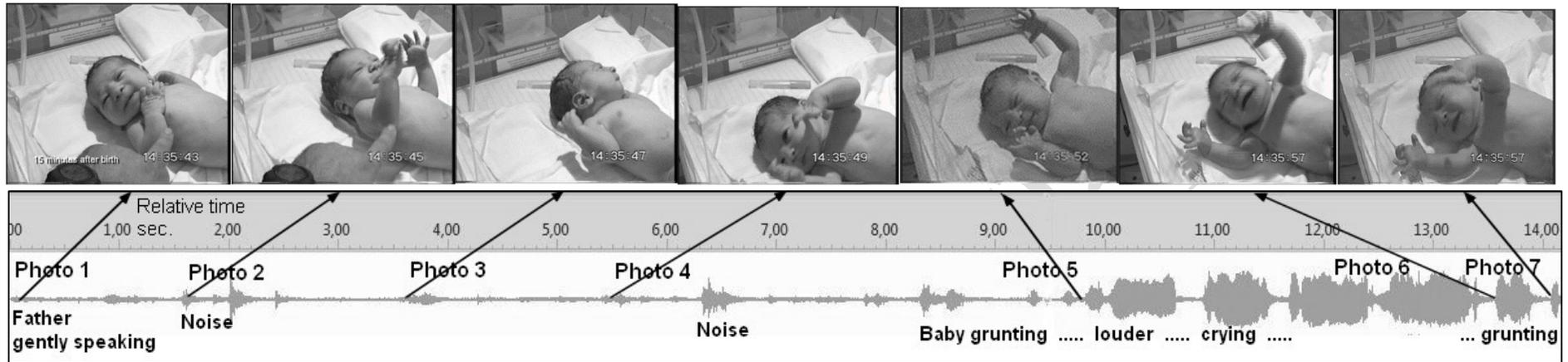


Fig. 1. Spontaneous Moro behavior 15 minutes after birth.

Subject	Relative time	Events
Newborn	00,00 s	Photo 1 Newborn supine on the nursing table, silent, head turned right, face neutral, eyes half open, arms flexed
Father		The father is gently speaking, left index finger caressing baby's right arm
Mother		The mother is lying on the delivery table, not visible on the right of the photo
Newborn	01,68 s	Photo 2 Sudden noises. Baby's head moved quickly to the midline, eyes blinking, arms raised vertically in extension-adduction, hands half open, left fingers spread, face neutral eyes half closed
Father		The father is still caressing the baby's right arm
"	03,24 s	Photo 3 The father stopped talking, withdrew his index finger, and remained close to the baby
Newborn		The baby turned his head and body to the left, forearms flexed beside the body, right hand close
"	05,48 s	Photo 4 The baby's head and body quickly turned to the right, fingers close, eyes open, face neutral, arms half flexed in shape arc adduction with disorderly movements and tremors
"	06,30 s	Sudden noise : no visible reaction of the baby
"	08,35 s	The baby is grunting louder and louder, body turned right, gradually raising both arms in extension-abduction
"	09,84 s	Photo 5 The baby begins to cry, eyes closed, arms progressively in extension-abduction, fingers spread
"	13,60 s	Photo 6 The baby is crying, eyes closed, face distressed, arms in full extension-abduction, fingers spread with tremor
"	14,10 s	Photo 7 The baby quickly lowers both arms in adduction towards his father and starts again to grunt for a few minutes

Notes: (s) = seconds; Cohen Kappa between independent observers (PVR & FM-AW): 0.81.