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



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ABSTRACT

Objective: To propose a phylogenetic significance to the Moro reflex which remains unexplained since its publication in 1918 because both hands are free at the end of the gesture. **Method:** Among the 75 videos of healthy term newborns we have filmed in a research project on antenatal education to parenthood, we describe a sequence that clearly showed the successive movements of the Moro reflex and we report the occurrence of this reflex in the videos that were recorded from Time 0 of birth defined as the moment that lies between the birth of the thorax and the pelvis of the infant.

Results: The selected sequence showed the following succession of the newborn's actions: quick extension-adduction of both arms, the 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. There were 13 Moro reflexes between 2 and 14 s from Time 0 of birth. We found a significant association between the occurrence of the Moro reflex and the placement of the newborn at birth in supine position on the mother's abdomen ($p = 0.002$).

Discussion: The quick extension-adduction of both arms which started the sequence may be considered as a startle reflex controlled by the neural fear system and the arm extension-adduction which followed as a Moro reflex. The characteristics of all Moro reflexes were those of ritualization: amplitude, duration, stereotype 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. The gestures associated with the Moro reflex: crying and orientation of the body, head, and eyes towards a human person, are gestures of intention to communicate which support 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 significance to the Moro reflex: a ritualized behavior of nonverbal communication. Professionals should avoid stimulating the newborns' fear system by unnecessarily triggering Moro reflexes. Antenatal education should teach parents to respond to the Moro reflexes of their newborn infant by picking her up in their arms with mother talk.

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1. Introduction

In 1918, Moro described that if a baby was 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 considered as labyrinthine reflexes (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 gestures 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 "*Umklammerungsreflex*" (embracing or clasping reflex). To support his hypothesis, Moro drew a young orangutan to show how it clings to the body of the 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 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 (Dubowitz, Ricci, & Mercuri, 2005; Zafeiriou, 2004), and its persistence beyond 6 months is significantly associated with Attention Deficit and Hyperactivity Disorder (ADHD) in children aged 8–11 years (Koncarova & Bob, 2012).

Moro's view that the reflex disappears after the third trimester in normal children was not confirmed by further research. A filmed follow-up of about fifty newborns every 10 days during the first postnatal trimester showed that the Moro reflex triggered by the method of head dropping did not disappear completely, but that it was gradually transformed into infant active behavior (Lamote De Grignon, 1955). Observation of toddlers showed that when they play close to their mother sitting on a chair, they regularly come in front of her, raising the arms up to be picked up in a similar way to the Moro reflex gestures (Anderson, 1972).

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 must 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 significantly more outward than inward arm movements, while a sudden 96 dB noise stimulus elicited significantly more inward than outward arm movements (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 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 because it lost its physiological function when both the infant's hands are free (Futagi, Toribe, & Suzuki, 2012; Prechtl, 1965).

While preparing a DVD from the 75 human birth videos recorded in a research project on antenatal education for parenting, we observed that many Moro reflexes were not caused by one of the usual stimuli: head dropping, knocking both hands on either side of the changing mat as practiced by pediatricians to verify the integrity of the newborn's nervous system. These Moro reactions were observed at or shortly after birth, during the care given to the newborns, or even spontaneously when they were lying supine. To try to understand the phylogenetic significance of the Moro reflex, we performed a micro-analysis of a Moro reflex that was not caused by one of the usual stimuli and we reanalyzed the 31 videos that were filmed from the beginning of birth. The method we used to analyze these videos was that of ethology, which has been defined as the biological study of behavior to answer the question: "Why do these individuals behave as they do?" (Tinbergen, 1963).

2. Methods

2.1. Participants

Our project of studying the early interactions between the newborn and her parents for improving antenatal parenting education was presented from December 1999 to May 2003 to a continuous series of 294 pregnant women during their prenatal appointments with the approval of the Ethics Committee of the Hospital. The inclusion criteria for filming births were the availability and ability of a member of the obstetric team or the father of the child to manipulate the camera and keep it focused on the newborn's face. We were thus able to film 75 births with the written consent of both parents for us to use the videos for scientific and educational purposes.

Amongst the 31 videos that were recorded from Time 0 of birth defined as the moment that lies between the birth of the thorax and the pelvis of the infant, the inclusion criteria for the present study were the newborns who were active continuously from Time 0, gestational age 37–41 weeks, spontaneous or induced labor with or without epidural analgesia, cephalic presentation, non-pathologic fetal heart monitoring, spontaneous vaginal delivery, clear amniotic fluid, a 5 min Apgar score at or above 7, newborn placed on the abdomen of the mother for immediate skin-to-skin contact. The exclusion criteria were the 8 newborns who had an Immobility Reaction at birth or shortly thereafter (Rousseau et al., 2014), the Moro reflexes that occurred when a newborn was placed on a scale or care table, those elicited by a pediatrician using one of the usual stimuli (head dropping or knocking both hands on either side of the head of the infant lying supine on the examination table), maternal hypertension, smoking, gestational diabetes, general anesthesia, breech presentation, instrumental or cesarean delivery, and resuscitation or malformation of the newborn. The study sample was 23 newborns, 15 boys and 8 girls.

2.2. Procedure

To analyze the videos, we followed the four steps of the research in ethology proposed by Tinbergen: 1) select an observation that clearly shows the characteristics of the behavior under study, 2) describe this observation in detail and look for its occurrence, 3) investigate the cause of the behavior, and 4) try to understand its survival value (Tinbergen, 1963).

Identifying spontaneous Moro behaviors was 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 standard. The qualitative description of the selected observation for this article was carried out using The Observer XT 12 software (Noldus Information Technology, Netherlands) which calculates the Cohen Kappa test to check the reliability of the data collected by two independent observers (PVR & FM). 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. Statistical analyses were conducted using the IBM SPSS 22 software. The Pearson's *r* test was used to check the reliability of quantitative data collected by two independent observers (PVR & RL), the T test to compare means of paired data, and the two-sided Fisher exact test to search for relationships between the Moro reflex and various variables. P value was considered as significant when <0.05 .

3. Results

3.1. Qualitative description

A 14 s video clip which showed two successive bilateral arm extension behaviors in a human newborn was selected among numerous sequences of Moro gestures (Fig. 1, Photos 2 and 6). At the beginning of the sequence, a healthy male term newborn, aged 15 min, 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 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

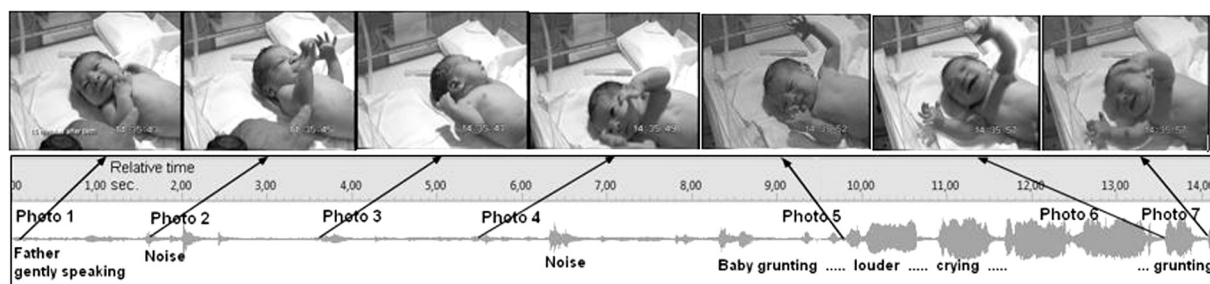


Fig. 1. Spontaneous Moro behavior 15 min after birth.

vertically, fingers were spread, hands were very close together, and the right hand was half flexed (Photo 2). This bilateral arm extension-adduction behavior can be considered as a Startle Reflex.

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, then he began to cry very loudly, eyes closed in a distressed face, the left arm raised progressively, and then both arms raised 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.

3.2. The Moro reflex at birth

We observed 13 Moro's reflexes amongst the 23 newborns who were continuously active since Time 0. They occurred between 2 and 14 s (mean: 7.6 s) from Time 0 of birth, all after a Startle reflex with a significant average delay of 5.7 s (95% CI [3.2, 8.1], $p < 0.001$) and after the first cry with a non-significant average delay of 0.6 s (95% CI [-2.5–3.7], $p = 0.671$). The average delay between the Startle and the first cry was significantly different (mean 5 s, 95% CI [1.9, 8.2], $p = 0.004$). (Table 1). The 13 newborns continued to cry with a distressed face after the Moro reflex.

Among the 10 newborns who were placed in a supine position at birth, the Moro reflexes occurred during the displacement in 7 cases and during face rubbing or mouth cleaning in 3 cases. Among the 3 newborns who were placed in a lateral decubitus position at birth, the Moro reflex occurred when they were moved, two by the nurse and one by the mother. In 4 videos, the delay between the Startle and the Moro reflexes was above the average of 5.5 s. In cases 1 and 7, the increased delay between the two reflexes is only apparent because the Moro reflexes occurred immediately after a second Startle reflex. In case 21, a first Moro reflex might have occurred when the newborn was not visible for 6 s; in case 30, the newborn's arms were held by the obstetrician and the Moro reflex occurred when she was turned in a supine position.

There was a significant association between the occurrence of the Moro reflex and the placement of the newborn at birth on the mother's abdomen ($p = 0.002$) and no association with maternal primiparity, prenatal stress, Group B streptococcus carriers, agitation during delivery, newborn's gender male, labor induction, epidural anesthesia, fetal scalp electrode placement, and full versus half-light in the delivery room (Table 2).

4. Discussion

4.1. Interpretation and significance

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: start of movement at a sudden noise, fast arm extension-adduction, eyes blinking, approximation of both hands, fingers moderately spread, and half-flexed right hand at the acme of movement, as described by Hunt, Clarke, and 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 are in brain subcortical structures, and not to describe the emotion itself (Panksepp & Biven, 2012, p. XI). The arm adduction and the proximity of the hands at the movement acme suggest that the startle reflex could be an attempt to cling inherited from our tree-dwelling ancestors.

The second behavior of the video clip (Fig. 1, Photos 3–6) was a double body tilting to the left, then to the right with open eyes, and followed by a full extension-abduction movement of both arms with spreading of the fingers, grunting, then shouting with a distressed face. The bilateral arm extension-abduction movement of Photo 6 (Fig. 1) is like the drawing by Moro in his original publication (Moro, 1918; Fig. 3) and can be regarded as true Moro gestures.

Table 1

Startle reflex, first cry, and Moro reflex at birth in 13 newborns active from Time 0 of birth.

Case N°	Newborn supine	Delay from Time 0 of birth [*]			Difference [*]			Circumstances of the Moro reflex occurrence
		Startle reflex	First cry	Moro reflex	Startle – First cry	Startle – Moro	First cry – Moro	
1	1	0.0	14	10.0	14.0	10.0	–4.0	2d Startle and Moro reflexes when turned in the supine position at T 11 s
2	1	2.0	2	3.0	0.0	1.0	1.0	Startle and Moro reflexes during being placed on the mother's abdomen
3	1	1.5	5.5	6.5	4.0	5.0	1.0	Moro reflex when the face being rubbed
7	1	1.0	12	14.0	11.0	13.0	2.0	2d Startle and Moro during the mouth being cleaned at T 13.5 s
10	1	1.0	4	2.0	3.0	1.0	–2.0	Moro reflex during being placed on the mother's abdomen
13	1	1.5	14.5	5.0	13	3.5	–9.5	Moro reflex when placed in the supine position
21	1	2.0	4	14.0	2.0	12.0	10.0	Moro reflex during the face being rubbed
30	1	3.5	5	12.0	1.5	8.5	7.0	Moro reflex when being turned in the supine position
36	1	0.5	11.5	6.0	11.0	5.5	–5.5	Moro reflex when being placed in the supine position
46	0	2.5	5.5	7.0	3.0	3.0	1.5	Moro reflex while rubbed and moved in the left lateral position
55	0	4.0	4	5.0	0.0	1.0	1.0	Moro reflex while being turned in the left lateral position by the mother
71	0	2.5	4.5	6.0	2.0	3.5	1.5	Moro reflex while being turned in the right lateral position by the nurse
75	1	3.0	4	8.0	1.0	5.0	4.0	Moro reflex while being turned in the supine position by the nurse
Mean		1.9	7.0	7.6	5.0	5.7	0.6	
Median		2.0	5.0	6.5	3.0	5	1.0	
SD		1.7	3.4	3.9	5.2	4.1	5.1	
Minimum		0.0	2.0	2.0	0.0	1.0	–9.5	
Maximum		4.0	14.5	14.0	14.0	13.0	10.0	
Pearsons' r [†]		.768	.689	.970				
Test T for paired data 95% CI					1.9–8.2	3.2–8.1	–2.5–3.5	
p					.004	<.001	.671	

T: Time from Time 0 of birth.

^{*} Time in second; SD: Standard Deviation.[†] Pearsons' r between two independent observers (PVR and RL) for the Startle, First cry, and Moro reflexes, p: two-sided Fisher exact test value.

The interpretation of the Moro reaction so far remained incomprehensible because the loss of any physiological function when the infant's both hands are free remained incomprehensible (Futagi, Toribe, & Suzuki, 2012; Prechtl 1965). Careful observation of Photo 6 (Fig. 1) detected features that caught our attention. The magnitude of arm abduction-extension and fingers spreading, the rigid posture at the acme of movement, and the stereotyped shape of the movement are features of ritualization which 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 (Eibl-Eibesfeldt, 1975, p. 213; Huxley, 1966). Induction of these observational facts into the concept of ritualization led us to the assumption that in human newborns who cannot move nor support their own weight by clinging to their mothers, the physiological behavior of grasping was transformed during evolution into a nonverbal

Table 2

Moro reflex associated factors in newborns continuously active since Time 0 of birth

Study sample: N = 23 Variable: present vs absent	Moro present N (%)	Moro absent N (%)	p
Mother			
Primiparity vs Multiparity	6 / 6 (100)	11 / 17 (64.7)	0.144
Prenatal stress	8 / 10 (80)	4 / 13 (69.2)	0.66
GBS	5 / 6 (83.3)	12 / 17 (70.6)	1
Mother's agitation	3 / 5 (60.0)	14 / 18 (77.8)	0.376
Neonate			
Gender male vs female	11 / 15 (46.7)	6 / 8 (75)	1
Labor management			
Induction	7 / 12 (58.3)	10 / 11 (90.9)	0.155
Epidural anesthesia	10 / 14 (71.4)	7 / 9 (77.8)	1
Fetal scalp electrode*	10 / 12 (83.3)	6 / 9 (66.7)	0.611
Early neonatal management			
Light: full / half-light	12 / 17 (70.6)	5 / 6 (83.3)	1.00
Supine vs lateral position	9 / 9 (100)	4 / 14 (28.6)	0.002

Note. p: two-sided Fisher exact test; GBS: Mother positive for Group B streptococcus; * No data for the 2 newborns; Supine vs lateral: newborn's first position on the mother's chest.

communication behavior. Re-analysis of Photos 3–5 (Fig. 1) detected other gestures associated with the Moro reflex: double body tilting, the 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 several minutes. These gestures are arguments in addition to that of ritualization for considering the Moro reflex as a nonverbal communication behavior because they denote the intention to communicate among human infants as do young people of species that belong to the same clade, bonobos and chimpanzees (Gillespie-Lynch, Greenfield, Feng, Savage-Rumbaugh, & Lyn, 2013). The lack of significant delay between the first cry and the Moro reflex (mean 0.6 s, $p = 0.671$, Table 1) suggests that these two behaviors are associated during the first few seconds after birth. This association is another argument to propose that the Moro reflex would be a communication behavior because infants' cries are considered as signals sent to the human environment (Gustafson, Wood, & Green, 2000).

The hypothesis of the Moro behavior as an act of non-verbal communication cannot be accepted unless it meets several conditions. 1) This behavior must meet the criteria of the Innate Releasing Mechanism (IRM) which consists of two processes: an innate and/or acquired knowledge of some specific components of its environment and a coordination of species-specific movements that allows it to master the situation by an adapted chain of three components: a state of arousal called appetite, a specific stimulus, and an act of consumption (Lorenz, 1978). The newborn's state of arousal could be caused by the supine position, the specific stimulus was the proximity of a human being, the father, and the consummatory action was the Moro's communication behavior (Fig. 1). 2) The level of awareness of the newborn must be sufficient so that s/he can 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 can act in a multimodal fashion on his or her physical and human environment (Rochat, 2010). 3) People who perceive this 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 newborn's Moro behavior, but the nurse responded by holding him in arms. 4) The newborn's behavior must be affected by the response given to his or her request. He continued to send distress signals while left in the supine position (Fig. 1, Photos 6 and 7), but he calmed down as soon as he was picked up in the arms by the nurse.

The neural mechanisms of the Moro reaction are less known than those of the Startle reflex which 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 neural network has not so far been described. In the 13 newborns of the study, all Moro reflexes occurred after a Startle reflex. This association makes it possible to propose, as Moro thought, that his eponymous reflex could also be controlled like the Startle reflex by the FEAR system and can therefore be understood as an active defense behavior of the flight, fight, freeze system in the human newborn who cannot move and replaces fleeing by a gesture of communication to its human environment.

The FEAR system is probably not the only neural network involved in triggering the Moro reflex when it is accompanied by gestures that indicate an intention to communicate (Fig. 1, Photos 3–6). The crying face of the newborn who did not receive any response suggests that the GRIEF/PANIC or separation-distress system could also be activated as it is in young animals separated from their mothers (Panksepp & Biven, 2012, pp. 313–316). The non-significant average delay of 0.6 s, we found between the first cry and the Moro reflex occurrence, is an argument towards the separation-distress system involvement because infants' cries are considered as graded signals that reflect the degrees of distress sent to the mother or other caregivers (Gustafson, Wood, & Green, 2000). Appeasement after being held in the arms showed that it was the adequate response. This maternal behavior is probably activated by the primary emotional CARE system. It was significantly

more effective than mother-talk alone to calm a crying newborn and to elicit the alert state which is necessary for her development (Thoman, Korner, & Beason-Williams, 1977).

The significant association we found between the supine position and the Moro reflex at birth (Table 2) questions the survival value of the evolutive transformation of the Startle reflex from a grasping behavior to a communicating one. The answer to this question might be the sitting position of the first women of the human species who gave birth on the floor as illustrated in Fig. 2.9. (A) of the Human Ethology monograph (Eibl-Eibesfeldt, 1989, p. 31). Lying supine, this just born human infant was exposed to predators, snakes, scorpions, and insects. Screaming with arms outstretched towards her mother as did the newborn of the photo in a typical Moro reflex was probably the best way selected by evolution to ensure her survival.

The Moro behavior we observed 15 min after birth (Fig. 1) was different from the 13 Moro reflexes which occurred during the first seconds after Time 0. It was preceded by gestures that indicate the intention to communicate: eye opening, vocalizations, and the orientation of the outstretched arms towards the father. The addition of these gestures and their orientation towards a human person suggest the previously described evolution of a primitive reflex towards an infantile behavior would begin sooner than previously described (Anderson, 1972; Lamote De Grignon, 1955). This hypothesis should be confirmed by future research as it has been done for the study of the functional reorganization of neural circuits that controls the evolution of the newborn's primitive stepping reflex towards independent walking (Ivanenko et al., 2013).

4.2. Possible implications

The idea based on the ethological concept of ritualization that the Moro reaction reflex is a ritualized behavior of nonverbal communication triggered by maybe both the FEAR and the GRIEF/PANIC systems opens important clinical perspectives for obstetricians, midwives, pediatricians, and practical perspectives for developmental and educational psychologists.

The fact that Moro's reflex was preceded by a Startle reflex in all the newborns of this study should remind clinicians that 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). Pediatricians are invited to verify whether the systematically triggering the Moro reflex by the usual stimuli to check the newborn's nervous system could be replaced by careful observation of complete and symmetric Moro behaviors that occur spontaneously in most of the cases at birth or during neonatal care. Birth practitioners should reduce intense visual and auditory stimuli during the birth process. Is not possible to avoid all Moro reflexes in obstetric practice, but it should be possible to avoid some of them by paying attention to the gestures which were associated with this reflex: displacing, turning in the supine or lateral position, drying the newborn, cleaning the mouth (Table 1). Attention should also be paid to the placement of the newborn on a scale, on a baby mat/examination table and during neonatal nursing procedures.

It is of course not always possible to avoid triggering a Moro reflex, but when it occurs, the newborn's FEAR and GRIEF/PANIC systems should be appeased by the appropriate response to the non-verbal message it sends, that is the request to be taken in the arms. To be hugged with mother talking is significantly more efficient than mother talk alone to soothe a crying infant (Thoman, Korner, & Beason-Williams, 1977). Instead of leaving the crying newborn unanswered after a Moro reflex, picking a baby up, putting her over the shoulder and talking to her can be a first social commitment that brings the fear appeasement that is necessary for the establishment of affective ties, attachment in the child and bonding in the mother and/or in the father (Porges, 2005).

In the 31 filmed births that were included in this study, no parent took the infant in his/her arms to appease her after a Moro reflex. The mother's and father's unsuccessful attempts to stop their baby crying only by soothing vocalizations This was probably 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 therefore inform parents about the human newborn's abilities to communicate by gestures like the Moro behavior so that they can respond adequately to this request to be taken in arms to be secure, which is one of their primary needs at birth (Bowly, 1969). In the delivery rooms, professionals should help parents to give more freedom to their spontaneous gestures during the first affective social interactions with their newborn baby. But before recommendations can be made to change maternity ward routines and antenatal education, further studies are needed to assess the negative and positive effects of systematically taking the newborn in the arms after a Moro reflex at or just after birth.

4.3. Strengths and weaknesses of the study

The strength of this ethological study is to propose for the first time a hypothesis to the significance of the Moro reflex which remained difficult to understand for nearly a century. This explanation involved two steps (Chalmers, 1976; Tinbergen, 1963). First, the interpretation of observed facts was 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 significance was based on the semantic content, the meaning of the message, that is a request to be picked up in the arms that can be understood as an active defense behavior of the flight, fight, freeze system in the human newborn when facing the danger of being thrown into a completely new environment.

A second interest of the study is to open several areas for further research to study: 1) the neonatal effects of taking in the arms the newborns who are performing a Moro reflex, 2) the possibility of removing stimuli of the FEAR system that would

impair the child emotional development by systematically triggering Moro reflexes to check the integrity of the nervous system, 3) the effects of being hugged at birth on the development of the mode of attachment of the child to her mother, and 4) the reorganization of the neural circuits that control the evolution of a primitive non-verbal communication behavior towards a more elaborate behavior during child development.

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 are present in the 31 videos. The main criterion was the technical quality of the video that helped cutting the newborn's behavior into consecutive gestures (Fig. 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 Fig. 1: quick adduction of both arms, head turned towards the examiner, extension-abduction of both arms, spreading of the fingers, distressed face, and screams, 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 evolutive process of ritualization was not known. He was probably right when he proposed that this behavior occurred as a reflex caused by fear. However, his interpretation does not seem complete when his eponymous reflex is accompanied by gestures that indicate the intention to communicate in newborn infants facing the stress of birth. This reflex is probably triggered by both the FEAR and the GRIEF/PANIC primary emotional systems. Professionals should try to reduce unnecessarily triggering Moro reflexes and to modify the birth rooms routines to give parents more freedom to soothe their infant soon after birth. Antenatal education should teach parents the meaning of the Moro reflex and prepare them, primarily the mothers, to respond to the Moro reflexes of their newborn infant by picking up her to their arms when they express fear or distress.

Conflict of interests

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

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