

# *From Imitation to Conversation: The First Dialogues with Human Neonates*

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The functional maturity of the newborn infant's brain, the resemblances between neonatal imitation and imitation in adults and the possibly lateralized neonatal imitation suggest that the mirror neuron system may contribute to neonatal imitation. Newborn infants not only imitate but also initiate previously imitated gestures, and are able to participate in overlapping imitation–initiation communicative cycles. Additionally, these social responses in neonates are faster than previously thought, and may enable them to have long-lasting intimate interactions much before language develops. Infants are equipped with a powerful, innate, reciprocal communicative ability already at birth. The earliest communication originates from imitation and this communicative ability presumably later evolves to language. Copyright © 2006 John Wiley & Sons, Ltd.

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## IMITATION: THE DEBATE

The word 'imitation' originates from the proto-Indo-European; from '*im*' and '*eto*', with the base '*aim-*' and 'copy'. 'Imitation, then, is one instinct of our nature' 'and no less universal is the pleasure felt in things imitated' (Aristotle, 1996).

Even though the word imitation is ancient, and Aristotle assumed that imitation was an universal human instinct, emotional, and rewarding; the cognitive developmental approach of the 20th century (Piaget, 1962) claimed that imitation of movements not seen on one's own body (such as tongue protrusion or other facial movements) occur at the earliest from 8 to 12 months of age and it is only after 12 months that the infant regularly imitates such movements.

A series of studies from the 1970s however, found that infants as young as a few hours old could imitate various gestures such as mouth, tongue, eye, hand, arm and leg movements (Heimann, Nelson, & Schaller, 1989; Kugiumutzakis, 1985; Maratos, 1973; Meltzoff & Moore, 1977; Reissland, 1988). Despite these

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findings however, neonatal imitation remained a controversial 'fuzzy phenomenon' (Heimann, 2001), and was even regarded as an artefact (Anisfeld, 1996). Although various models of imitation, ranging from ethological (Jacobson, 1979) and learning theories (Miller & Dollard, 1941) to intermodal matching (Meltzoff, 1988a,b) and the mirror neuron system model (Iacoboni *et al.*, 2001; Wohlschlagel & Bekkering, 2002) successfully explained some aspects of imitation, they failed to explain why babies started to imitate and what the motivation is for their first imitations.

Neonatal imitation is defined as various facial, hand, and finger movements and vocalizations made by a young infant in a laboratory environment shortly after an experimenter has modelled the same behaviour to the infant. Imitation, as described in laboratory communication paradigms, requires the infant to show orientation, attention, learning, effort and motivation when reproducing the previously modelled movements or sounds (many of which are quite unnatural or artificial). It is likely that the search for a unifying theory of imitation will fail to describe all types of imitations, as more types of imitations exist with potentially different mechanisms. Early researchers of the field (Gardner & Gardner, 1970; Maratos, 1970) reported a U-shaped curve, an early decline and later rise of the imitation during infancy. It is likely that imitation arising at later infancy is directed by different mechanisms than neonatal imitation.

## A NEURAL SYSTEM SUBSERVING IMITATION IN HUMANS

Recent research has suggested that primates and humans have a tendency to imitate an observed motor act if it is already present in their motor repertoire (Rizzolatti & Craighero, 2004). Not only human but also neonatal chimpanzees are able to imitate facial actions (tongue protrusion or mouth opening) and this ability, as in humans, declines after 2 months of life (Myowa, 1996).

A complex neural circuit, the mirror neuron system has been described as a neural substrate of understanding and responding to the biological actions of others (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996; Tai, Scherfler, Brooks, Sawamoto, & Castiello, 2004). Neurons in the area F5 (in the ventral premotor cortex; human homologue is the Brodmann 44 area), and in the area 7b (the rostral inferior parietal lobule) form the mirror neuron circuit with some other brain areas such as the superior temporal sulcus. The F5 neurons in the premotor cortex of the monkey respond to the visual or, in some cases, auditory (Kohler *et al.*, 2002) stimuli of others' actions (for example hand or mouth movements) as well as when performing the action. Neurons in the superior temporal sulcus are responsive to a wide range of observed actions, such as walking, head turning and arm and body movements.

The human mirror neuron system (unlike the monkey's) responds not only to object-related actions, but also to meaningless movements, such as simple finger movements (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995), which probably represents an important evolutionary step toward the development of complex communication systems (Arbib, 2004). Moreover, the system is probably tuned to be resonant with others around us, but not with movements of robots or movements involving tools (Tai *et al.*, 2004). Escola *et al.* (2004), however found that when a tool is acting like a hand and monkeys recognize this similarity, then the mirror neuron system responds even to movements made with tools.

The reason that we do not imitate everyone all the time—that is, that the function of the mirror neuron system does not lead to an automatic imitation of

every movement that others are exhibiting—is an inhibitory mechanism in the spinal cord (a spinal H reflex results in antagonist muscle activation; Baldissera, Cavallari, Craighero, & Fadiga, 2001). Therefore although we have an inbuilt sensitivity to understand and an inbuilt neural mechanism to copy others' action, further regulatory mechanisms offer the 'free will' (in the format of inhibition) for a greater selection of the potential reactions.

In summary, there is a neural system both in humans and monkeys which is biologically tuned to understand and sympathize with others, and is biologically primed to a resonant, empathetic response, but is also equipped by further regulatory mechanisms to free us up to react with highly organized responses.

## MIRROR NEURON SYSTEM IN NEONATES?

A growing number of neuroimaging studies have proven that the mirror neuron system is indeed involved in human imitation. In Iacoboni *et al.*'s (1999) study, the left frontal operculum and the right posterior parietal cortex was activated during imitative movements. Regardless of the nature of the imitation, whether it was the imitation of hand or facial movements, the Brodmann 44 area, including the Broca's area, the bilateral dorsal and ventral premotor areas, the right superior temporal gyrus, and the supplementary motor area were reported to be activated (Leslie, Johnson-Frey, & Grafton, 2004). Additionally, when observing an action, a 'copy' of the action is activated in the premotor cortex of the observer in a somatotopical way paving the way for mirroring (Buccino *et al.*, 2001).

There are functional resemblances between neonatal and adult imitation. Tai found that the mirror neuron system in the observer is activated only by human actions, but not when a human model uses a tool to perform an action or when a robot performs such an action (Tai *et al.*, 2004). Infant imitation, like that in adults, is more sensitive and more responsive to actions demonstrated by a person than by objects (Legerstee, 1991).

Although even newborn infants are able to imitate, we have no information about the neural mechanisms of neonatal imitation, and whether the main structures of the mirror neuron system are mature enough to subservise neonatal imitation. Studies using event-related potential (ERP) measures reported the functional activity of both the frontal and the temporal lobes in neonates and young infants. Two-month-old infants activated their left superior temporal and inferior frontal gyri (regions in adults associated with language processing) when they were watching human faces (Tzourio-Mazoyer *et al.*, 2002). Newborn infants activated the fronto-central areas and the left superior temporal gyrus (a phonetic network in the brain similar to that of adults) during categorical perception of phonemes (Dehaene-Lambertz & Pena, 2001). The mismatched negativity ERP over the temporal areas was reported to occur at 292 ms in newborns (Dehaene, Lambertz, & Pena, 2001), which is similar to although slower than in adults at 80–160 ms (Naatanen, Gaillard, & Mantysalo, 1978). The temporal cortex, however, is able to generate this potential in newborns (Cheour-Luhtanen *et al.*, 1995; Huotilainen *et al.*, 2003) and many other ERP components (P150, N250, P350 and N450 ERPs) can be elicited after birth, even though they are usually with a longer latency (Kushnerenko *et al.*, 2002). Cortical generators of the ERP peaks therefore are functioning at birth, even though further maturational changes are needed for the development of the adult waveform morphology.

In summary, the functional activity of the key cortical areas (frontal and temporal areas) may contribute to the appearance of imitative motor movements in

newborn infants. However, even if so, there is no evidence yet to show that the same neural mechanisms are indeed responsible for neonatal imitation as it is reported in human adults. Even though the cortex is functionally active in the neonate, the potential role of subcortical areas must also be taken into account. Besides the primary sensory cortex, motor cortex and the hippocampus, subcortical areas such as the thalamus and the brainstem have the highest glucose metabolism in the newborn brain (Chugani, 1998). Also, behaviours in the neonate are not necessarily guided by the same neural mechanisms as in adults. Visual perception for example does not necessarily require the functional involvement of the visual cortex. Neonates, who later proved to be cortically blind, were able to orient to and follow objects visually in their first month of life before losing this skill (Dubowitz, Mushin, De-Vries, & Arden, 1986). In young infants, brain lesions involving the basal ganglia were more likely to be associated with impaired visual function than lesions of the occipital cortex; especially involvement of the putamen was always associated with abnormal visual functions (Mercuri *et al.*, 1997). Neural conduction time from the motor cortex, for example, is three times longer in neonates than it is in adults, although the speed of the actual movement is not reduced (Schieber, 1996). Even complex social behaviours can be guided by subcortical areas; an anencephalic neonate in a study by Luyendijk and Treffers (1992) showed a smile as a response to the stimulation of the pontine tegmentum. This means that the contribution of the subcortical processes to the behaviour is likely in neonates.

## A LATERALIZED SYSTEM FOR NEONATAL IMITATION?

As a first attempt we tried to explore the potential contribution of the mirror neuron system to imitation in human neonates. In an experiment (Nagy *et al.*, 2003, in press) we randomly modelled left- and right-handed index finger extension movements to 39 human neonates in their first 3–96 h of life. Imitative responses to this particular gesture can vary in laterality (left, right, or mixed), and in the relationship of the imitative movement to the relative position of the baby and the experimenter (specular, anatomic or random imitation). Therefore, we hypothesized that the predominant pattern of neonatal imitation can offer an insight into the understanding its mechanism. Index finger movements in the baseline period (an average of about 5 min), and in the response period were compared (response period is when the experimenter showed index finger protrusion movements the baby and then waited for an average of 50 s and then administered the next gesture). An average of 25 imitation periods were initiated by the experimenter. The frequency and the duration of the hand movements, both of the experimenter and the baby, were coded from time-stamped video records by a naive coder. In this ecological based coding system, all hand and finger movements on the video records were coded regardless of whether they were during the imitation or baseline period, and regardless of whether the movements were imitative or spontaneous. The results showed, that babies not only imitated the specific finger movement but also showed an interesting left-sided bias in the imitation but not during the baseline period. This means that babies tended to use their left index finger during imitations, regardless of the hand used by the model. Also, babies responded surprisingly quickly during these imitations. The first finger movement imitations occurred in an average of 25.23 s (S.D. = 45.93) after the first modelling, and the second imitation in 8.21 s

(S.D. = 16.00) after the next modelling, which is much faster than previously thought (Heimann, 2001).

So far, the majority of studies with neonates have used tongue protrusion gesture (Dunkeld, 1978; Heimann & Schaller, 1985; Heimann *et al.*, 1989; Kugiumutzakis, 1985; Meltzoff & Moore, 1977, 1983; Reissland, 1988), and only a very few studies with young infants have used leg and hand movement gestures (Maratos, 1973; Meltzoff & Moore, 1997). The researchers' preference for this gesture originates from the history of imitation research. Piaget (1962) projected the emergence of imitation of body movements that babies cannot observe on themselves (such as facial actions) for a stage later (Stage 4. at 8–12 months) than other movements that babies can observe on themselves (such as hand movements). Therefore most studies that have tried to prove the existence of neonatal imitation have concentrated on facial gestures, and especially on tongue protrusion, because these are movements that the baby cannot observe on her/himself. However, focusing on the tongue protrusion gesture in imitation studies has various limitations. The baseline frequency of this action is very high, therefore spontaneous and imitative movements cannot be distinguished easily (Heimann, 1989). Most researchers have overcome this limitation by using a cross-modal paradigm (Heimann and Schaller, 1985; Meltzoff and Moore, 1977). That is, they have attempted to elicit selective imitation by using two different gestures (mouth opening and tongue protrusion gestures). Employing more than one imitative gesture, however, could limit the investigation of the naturalistic, communicative function of the neonatal imitation. Also, the face, which is the interface for social communication, is 'used' as a tool for imitation, and the movement itself is easy for the neonates, and appears usually symmetrically, in the midline.

Finger and hand movement gestures during naturalistic situations have already been investigated in young infants (Fogel & Hannan, 1985; Legerstee, Corter, & Kienapple, 1990; Trevarthen, 1977). Fogel and Hannan (1985) found that discrete manual actions signal discrete emotional states and are used in communicative interpersonal situations from at least week 9.

Imitative finger movements, however, may also form the bases of communication, if the function of early imitation is communicative. The fine motor index finger gesture chosen in our studies are similar to those used in previous studies that describe the mirror neuron system model of imitation (Iacoboni *et al.*, 2001; Leslie *et al.*, 2004). The mirror neuron system of adults has lateralized components including Broca's area of the left hemisphere, the right superior temporal gyrus, and supplementary motor area, (besides the bilateral dorsal and ventral premotor areas) these being described as elements of a common circuit for imitation of various forms of movements. The laterality of the neonatal imitation may indicate that some of the components of its neural circuit maybe corresponding lateralized areas to the human mirror neuron system.

Through contralateral pathways, the early advantage of the right hemisphere (Chiron *et al.*, 1997; Schore, 2000; Trevarthen, 2001) in the first few months of life may affect the lateralized appearance of the first imitative gestures. The right hemisphere is dominant in emotional and face processing (Adolphs, Damasio, Tranel, & Damasio, 1996; Natale, Gur, & Gur, 1983), and emotional facial expressions in humans (Sackeim, Gur, & Saucis, 1978) and in chimpanzees (Fernandez-Carriba, Loeches, Morcillo, & Hopkins, 2002) are stronger on the left side. Thus, right hemisphere dominance for a hand gesture may suggest that neonatal imitation is not a simple isopraxism, but a motivated expressive behaviour.

On the other hand, given the fast response times during imitations, the role of the ipsilateral motor pathways should also be taken into account. The left ipsilateral motor pathway has a pronounced influence on fine, complex motor movements in adults (Chen, Gerloff, Hallett, & Cohen, 1997), and the ipsilateral pathways are relatively faster than the contralateral in infants (Eyre, Taylor, Villagra, Smith, & Miller, 2001).

In summary, our preliminary results suggest that human neonates may use a specific lateralized brain system for imitation, although further studies are needed to clarify this bias. In any case, the use of hand and especially independent finger movements could open new perspectives for behavioural observation studies in the search for the neural system underlying neonatal imitation. Whether this system is the same for monkeys and humans remains an open question.

A further question that needs investigation is how neonatal imitation relates to later imitation in infancy, childhood, and adulthood. Several studies in this area have reported a U-shaped curve, in which neonatal imitation tends to decline at about 6 weeks of life and then reappear later, possibly in a new format (Maratos, 1973), incorporating developing cognitive skills. This includes the capacity to store and represent information, which leads to delayed imitation (Heimann *et al.*, 2006; Meltzoff, 1988a,b). Systematic longitudinal studies would be needed to follow the changes and the development of imitation from the neonatal period to later infancy.

## NEONATAL IMITATION—THE FIRST DIALOGUES WITHOUT LANGUAGE

Moving beyond the mirror neuron theory, Arbib (2004) hypothesized that evolutionarily the mirror neuron system has developed to equip humans with a language-ready brain. During evolution, simple imitations in apes developed to more complex imitations (imitation of sequences) in humans, then to protospeech and finally to language. It is possible that imitation not only in evolution but also during ontogenesis is a precursor of later communication and language development.

Earlier studies demonstrated the interpersonal functions of early imitation. Imitation is a very effective call for another person's attention in young preverbal infants and even in toddlers. Nadel, Guerini, Peze, and Rivet (1999) found that 2-year-old toddlers can develop long interactions with a peer only by using imitation although they did not usually interact in other control situations. Imitation therefore goes much beyond learning, is not a solely cognitive process but rather a motivated behaviour to open and maintain intimate interactions long before babies have mastered language.

Most studies however, have examined neonatal imitation simply as a response to various stimulations in a controlled laboratory experiment. However, the natural purpose and the mechanism of imitation in young infants remain largely unexplored. If this imitation is interactive, constituting the language ready brain of newborn infants, then even newborns should be able to participate in imitation exchanges in a proactive way. If newborn infants take turns at certain points during imitative exchanges, this would demonstrate that voluntary communication motivated by a mechanism of prospective perceptual control is possible right after birth.

In our study (Nagy & Molnar, 1994, 2004) we explored this potential interactive nature of neonatal imitation using both behavioural and psychophysiological (heart rate) measures. Heart rate monitoring was a source to reveal the contribution of arousal indicated by heart rate acceleration, and of orientation, learning and expectance components as indicated by heart rate deceleration during imitation. In these studies, we found that newborn babies not only imitated gestures but also spontaneously started to initiate them (after several imitation cycles) and were waiting for the experimenter to respond (Nagy & Molnar, 1994, 2004). We called this phenomenon 'provocation', or neonatal initiation. As a laboratory definition for this 'provocation' phenomenon, we defined it as the baby producing a previously imitated gesture 120 or more secs after the experimenter's similar gesture or after the baby's own previous imitative response. The baby had to be looking at the experimenter. This combination of behaviours may indicate that the baby has initiated the gesture and is waiting for a response. In our study, several long-lasting 'dialogues' were initiated by newborn babies this way. That is, the baby 'initiated', the experimenter responded, the baby responded, the experimenter responded, and so on, in a precisely timed, very fast, overlapping reciprocal 'conversation'. Additionally, these imitations and initiations were accompanied by different psychophysiological patterns: while babies imitated their heart rate increased, and while they initiated their heart rate decreased, as if they were expecting a response (Nagy & Molnar, 2004). Imitation and provocation—two naturally otherwise intertwined phenomena—could thus offer a laboratory model of all human communication (see also Zeedyk, this volume).

The speed of the neonatal imitation showed that infants were fast enough in their social responses to be able to participate in communicative exchanges. Imitative responses also appeared faster than they were previously thought to occur. In Heimann's study (2001), tongue protrusion imitations started only around 1 min after the modelling, while in our study, finger movement imitations appeared on average of a half minute after the model. The reason for this difference was probably methodological. In the pioneer studies of Meltzoff and Moore (1977) and Heimann *et al.* (1989), the experimenter's continuous modelling was relatively insensitive to the baby's condition, attention and response, while our approach was more interactive and responsive. This experimental design is probably closer to the form of naturally occurring imitative exchanges. Thus babies may have been more responsive, motivated and faster in our study because imitation occurred in an interpersonal interactive setting.

In summary, initiation and imitation—innate abilities of the human infant—offer a laboratory model for all communication, namely responding and opening, the first turn-taking dialogues.

## SUMMARY

The functional maturation of the newborn's brain and the possibly lateralized neonatal imitation may support a claim that the mirror neuron system could contribute to neonatal imitation. Imitation offers a universal and innate mechanism for complex intersubjective communication not only for the sake of copying, learning, reproducing a movement or achieving the potential goal of the imitated movement, but for being connected to another person, through long-lasting intimate interactions. These are possible long before language develops. Infants, already at birth are equipped with a powerful innate reciprocal

communicative ability, which originates from imitation (an innate sensitivity to a sympathetic other human being, Trevarthen, 2001, 2003). This communicative ability presumably evolves later to language.

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