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Development of social cognition in infant chimpanzees (*Pan troglodytes*): Face recognition, smiling, gaze, and the lack of triadic interactions[1]

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Abstract: In this paper, we summarize a series of studies on the developmental changes in social cognition in mother-raised infant chimpanzees from birth to around 2 years old. The infants preferentially tracked a photograph of their mother's face at 1 month but showed indifferent preferences to faces at 2 months old. This change in facial recognition was correlated with a decrease in neonatal spontaneous smiling, increase in social smiling and a decline in neonatal imitation of facial expressions. Also at around 2 months, the infants began to show preferences for directed-gaze faces over averted gazes, and the amount of

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mutual gaze time between mother and infant chimpanzees increased. Thus, by 2 months of age, abilities required for dyadic interactions are already developed in chimpanzees as is the case in humans. The development of triadic interactions, however, is rather different between these two species. The infant chimpanzee can follow another's pointing or gaze at around 1 year, but even by 2 years old, does not "share" attention with the others.

Key words: social cognition, development, chimpanzees, gaze, triadic interactions.

Studies on social cognition in nonhuman primates from comparative and developmental perspectives have attracted much attention over the last 20 years. When Premack and Woodruff (1978) proposed the concept of "theory of mind," that is, the ability to infer another conspecific's mental state, they did so based on empiric study conducted with chimpanzee subjects. This idea was then elaborated on by the developmental psychologists and many experimental studies were conducted with human children using "false belief" tasks (e.g., Wimmer & Perner, 1983). In sum, researchers found that "theory of mind" is emergent only after 4 or 5 years of age and that 3-year-old children do not show any clear evidence for the understanding of "false belief" (Mitchell, 1997). Nevertheless, many researchers began trying to find the prerequisites for the 5-year-old's theory of mind in much younger children (Wellman, 1992). At the same time, a group of primatologists in the mid 1980s proposed the hypothesis that human intelligence evolved to deal with the complexities of social living (Byrne & Whiten, 1988; Whiten & Byrne, 1997). This hypothesis, called the social intelligence hypothesis or Machiavellian intelligence hypothesis, was linked with progress in human developmental psychology. Since then, comparative (evolutionary) and developmental approaches to social cognition have both been recognized as being important to the understanding of human social cognition. Throughout the 1990s, findings on various aspects of social cognition in nonhuman primates (especially the great apes) accumulated: tactical deception, imitation, observational learning in cultural behavior including tool use, gaze following, understanding of the relationship between seeing and knowing, empathy, social referencing, and false belief (e.g., Tomasello & Call, 1997; Whiten & Byrne, 1997).

However, many of these studies tested only adult subjects and, although they revealed the great ape's abilities in social cognition, the developmental course of these abilities is not still well understood. Developmental studies of captive chimpanzees had been conducted since the 1930s, but most used the human-raised infant chimpanzees (e.g., Kellogg & Kellogg, 1933; Hayes, 1951; Gardner & Gardner, 1969; Okano, 1978). It is quite plausible that interactions between the human caregiver and the infant would modify the emergence of abilities in social cognition (cf. Russell, Bard, & Adamson, 1997). To truly understand the comparative development of social cognition in great apes, we need to investigate the natural emergence of these abilities during the course of development. It was primarily for this purpose that the Primate Research Institute of Kyoto University (PRI) started a project of longitudinal study on chimpanzee development in 2000 (Matsuzawa, 2002, 2003; Tanaka, Tomonaga, & Matsuzawa, 2002; Tomonaga, Tanaka, & Matsuzawa, 2003). That year, three infants were born to chimpanzees at the PRI (Figure 1) and each mother successfully held her baby, demonstrating good maternal competence (e.g., Bard, 2002). Given the limitations imposed by captivity, we arranged as best we could the necessary conditions to facilitate the natural development of chimpanzees in regard to community and mother-infant bonds. Our research project ranges over various domains from physiological to cognitive aspects. In this paper, we focus on cognitive development in the social domain on the basis of mother-infant bonds: recognition of the mother's

Figure 1. Three mother-infant pairs of chimpanzees at the Primate Research Institute, Kyoto University. Left: Ai (mother) and Ayumu (male, born in April 24, 2000). Center: Chloe and Cleo (female, born in June 19, 2000). Right: Pan and Pal (female, born in August 9, 2000). (Photo courtesy The Mainichi Shimbun and Tetsuro Matsuzawa.)

face, mutual gaze, gaze following, and triadic interactions. These topics have recently been extensively discussed and are at the center of controversies concerning the evolutionary origin of primate cognition (Tomasello & Call, 1997; Tomasello, 1999).

Recognition of the mother's face

The mother is most familiar and important individual for the infant. Human infants start to recognize their mother's face as early as 4 days of age (e.g., Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995), with the average being around 1 month of age. We tested the three mother-raised infant chimpanzees on the recognition of their mother's face longitudinally from the first week of life with the preferential tracking procedure, used frequently in the study of face recognition in early infancy in humans (Johnson & Morton, 1991). We prepared two types of stimulus sets, the mother's face and a prototypic averaged chimpanzee face prepared by computer software based on the mother's face and those of the other members of the chimpanzee community at PRI (cf. Yamaguchi, Myowa, Kanazawa, & Tomonaga, 2000). We set a photograph onto the CCD camera and presented it in front of the infant's face (when they were being held by their mother) and moved the photograph slowly left and right five times. Appropriate eye movements or head turning were defined as "tracking responses" (e.g., Bard, Platzman, Lester, & Suomi, 1992) and the number of tracking responses to each photograph were compared.

The infants at the age of 0 months showed very few tracking responses and there was no difference in the response to either type of face. At 1 month of age, however, all of the infants exhibited more responses to their mother's face than to the averaged face. Later, however, they increasingly preferred both their mother's and the averaged faces non-differentially. Overall, the infant chimpanzees recognized their mother's face at least at 1 month of age, which generally corresponds to the results for human infants (e.g., Bushnell, Sai, & Mullin, 1989). The more important and interesting point to be noted, however, is that their tracking responses to the two types of faces were very high but not different when they were around 2 months of age.

From 1 to 2 months of age other important changes were also observed. First, Myowa-Yamakoshi, Tomonaga, Tanaka, and Matsuzawa (in press) investigated the developmental changes in neonatal imitation and found that the matched facial-expression responses to facial expressions made by the human experimenter decreased steeply to levels expected by chance. In the later period, the infants responded with an open mouth to all types of

the model's facial expression. Second, Mizuno and Takeshita (2002) found that spontaneous smiling responses devoid of external stimulations (intrinsic) during rapid-eye-movement sleep decreased at 1 month of age, whereas extraneous (or "social") smiling responses elicited by explicit stimulations to the infant, such as presenting objects and face-to-face interactions, increased from 1 to 2 months. We also frequently observed "playface" open-mouthed responses to photographs of faces during the later period of the face-recognition experiment. Although it is still controversial as to whether neonatal imitation in chimpanzees is reflexive or not, all of these results from neonatal imitation and smiling suggest that developmental changes occurred in chimpanzees from reflex-like (nonsocial) responses to social responses between 1 and 2 months of age. Taken together with the results of face recognition the abilities of social cognition emerge during this age period.

Mutual gaze

In parallel with the emergence of social reactions such as indifferent preferences to faces and social smiling, there are also developmental changes in the mutual gaze between the mother and infant (Figure 2). Mutual gaze is defined as when both the mother and infant look at each other's face (Emery, 2000). Through detailed observations on the development of mutual gaze using video recordings, we found that the three mother-infant pairs increased the occurrences of mutual gaze from 0 to 2 months of age: they established mutual gaze, on average, 28 times per hour in the latter period. This increase in mutual gaze corresponded to a decrease in cradling behavior by the mother. So, the frequency of mutual gaze is negatively correlated with that of physical contact between mother and infant, which is also the case in human mother-infant pairs (LaVelli & Fogel, 2002).

Figure 2. Mutual gaze between Ai (mother) and Ayumu (infant, at 1 month old). (Photo courtesy The Yomiuri Shimbun.)

We further tested whether the chimpanzee infants from 10 to 32 weeks of age actually discriminated gaze direction (Myowa-Yamakoshi, Tomonaga, Tanaka, & Matsuzawa, 2003). In humans, neonates younger than 2 days old looked at a photograph of a face with the eyes open for longer than at the same face with the eyes closed (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000). However, the majority of studies reveal that human infants can discriminate eye gaze direction only when they are 3–4 months old (Samuels, 1985; Vecera & Johnson, 1995; Farroni, Johnson, Brockbank, & Simon, 2000). In nonhuman primates, there are very few reports on the development of discrimination of eye gaze direction. Myowa-Yamakoshi and Tomonaga (2001) reported that a nursery-raised agile gibbon infant showed a preference for schematic directed-gaze face over an averted-gaze face when he was younger than 1 month.

We used a forced-choice preferential looking procedure (Figure 3), with various sets of photographs of human faces with directed and averted eye gazes. Directed- and averted-gaze faces were presented to the infants for 15 s and the time spent looking at each of the photographs was measured. All infants looked significantly longer at the directed-gaze faces than at the averted-gaze faces. These results may suggest that the infant preference for directed eye gaze preceded the mother's behavior of trying to encourage a mutual gaze. This speculation is given some support by our naturalistic observation that the amount of time that mothers spent looking at their infants' face was unchanged between 2 and 12 weeks of infant age (11% of the observation on average).

Figure 3. Setting for the gaze recognition experiment. The human experimenter presented a pair of photographs of directed- and averted-gaze faces to the infant. Looking behavior of the infant was recorded by the small CCD camera mounted between the two photographs.

Bi-directional mother-infant interactions on the basis of mutual gaze may facilitate "primary intersubjectivity" (Trevarthen & Aitken, 2001), defined as a dyad social relationship maintained by mutual gaze between mother and infant chimpanzees. Furthermore, in humans, the social functions of eye gaze develop beyond the dyad to those that involve a triad of the infant, social partner, and an object (i.e., shared attention; Emery, 2000). We discuss this developmental change in chimpanzees in a later section.

Gaze following

Chimpanzee infants, as young as 1 month old, initially discriminate the mother's face from others and their social-cognitive abilities emerged from 1 to 2 months of age as was evident in a decrease of reflex-like responsiveness. Based on these changes, they recognize another's eye-gaze direction, pay attention to directed-gaze faces, and engage in dyadic social interactions with the mother via mutual gaze. The next great developmental step for the infants is to allow the gaze of others to direct their own attention, that is, gaze following. Here, gaze following refers to when an individual detects that another's gaze is not directed toward him and follows the line of sight of that other individual onto a point or an object in space (cf. Emery, 2000). Human infants at around 6 months old begin to follow the gaze direction of others and this ability becomes more sophisticated during the course of development (Butterworth & Jarrett, 1991; Moore & Dunham, 1995). The ability to follow another's gaze has been intensively examined in various non-human primates from prosimians to great apes (see Emery, 2000 for review) but there are few studies on gaze following from the comparative-developmental perspective (e.g., Ferrari, Kohler, Fogassi, & Gallese, 2000; Tomasello, Hare, & Fogleman, 2001). Okamoto, Tomonaga, Ishii, Kawai, Tanaka, and Matsuzawa (2002) tested the ability of an infant chimpanzee to follow a human experimenter's social cues, including gaze, longitudinally from 7 to 13 months of age.

In their experiment, the human experimenter positioned outside of the experimental booth gave various types of cues to the infant, who was in the booth (Figure 4). The cues were directed to one of two identical objects, and consisted of tapping, pointing to it, head turning toward it, and only eyes directed to it. Three seconds after the presentation of the social cue, the experimenter delivered a food reward to that side, irrespective of the infant's responses. We defined a following response as the subject's looking or approaching the side

Figure 4. Ayumu at 17-months-old followed the experimenter's pointing. (Photo courtesy The Mainichi Shimbun.)

to which the experimenter attended before the delivery of food. The infant reliably followed the pointing cue before the age of 9 months, the head-turn cue by the age of 10 months, and eye-gaze cue (without head movements) by 13 months.

These experiments clearly showed that an infant chimpanzee did follow social cues, including gaze at around 9 months old. Although our experimental design was non-differential reinforcement testing to avoid learning by differential reinforcement, the infant in fact might have "learned" to follow human gaze through the outcomes given by the experimenter. Nevertheless, his performance was constrained by the type of social cues, especially in the latter phase of the experiment: pointing was easiest and eye gaze was the most difficult. This constraint may be due to the nature of social cues, such as saliency, to some degree, but we cannot rule out the possibility of developmental constraints. In this special issue, Okamoto, Tanaka, and Tomonaga (2004) report on the later changes in the same subject's gaze following ability. The subject at 20-months-old began to "look back" by following the human pointing to an object behind the subject. Taken together with these results, gaze following ability in chimpanzee infants seems to develop gradually and in a step-by-step manner, as has also been found in human infants. Needless to say, it should be further investigated as to whether this response was functionally identical to that in humans (Butterworth & Jarrett, 1991).

Triadic interactions

In humans, a great qualitative change concerning social communications occurs at around 9 months old (Carpenter, Nagell, & Tomasello, 1998; Ohgami, 2002). Human infants, at 6 months, interact dyadically with objects or with a person in a turn-taking (or reciprocally exchanging) sequence. However, they do not interact with the person who is manipulating the objects (Tomasello, 1999). At this age, the dyadic format of social interaction is prototypical, however, this format changes in a marked way from around 9 months on (probably up to 12 months) when they start to engage in triadic exchanges with others. Their interactions involve both objects and the person, resulting in the formation of a referential triangle of infant, adult, and the object upon which they share attention (Tomasello, 1999). The propensity of the infant to look up toward the adult and then back to the object demonstrates that the infant is checking the joint visual attention of the other person (Rochat, 2001). This behavior is called shared attention (Emery, 2000). Shared attention is different from gaze following and emphasizes the role of communicative interactions via gaze (cf. Emery, 2000). This is a decisive, critical development occurring at around 9 months of age. Some researchers refer to this change as "The 9-month revolution" (e.g., Tomasello, 1999). The 9-month revolution appears on the basis of the primitive but necessary ability of gaze following and understanding the intention or goal-directedness of others and then becomes the basis for understanding the other's mental state (Baron-Cohen, 1995; Tomasello, 1999).

Chimpanzees begin to interact with objects in a very simple manner at 3–5 months old, and show more complex, combinatorial manipulations at 8–9 months (Hayashi & Matsuzawa, 2003). They also begin to move away from their mother and search for something in the environment at around 4 months and start to interact with other individuals, including human experimenters, at around 6-to-8 months (Nakashima, 2003). Like human infants, their interactions with others are all emotionally based (e.g., with facial expressions; Figure 5).

The 9-month revolution, however, does not seem to occur in chimpanzees, although the conclusion is still not decisive (Tomasello & Call, 1997). Our studies also provide, at present, no affirmative results. In an opportunistic observation, we tried to engage in triadic exchange with the chimpanzee infants using various kinds of objects but they did not interact with humans in a reciprocating manner. When the human experimenter played with the infant chimpanzee at the age of 1–2 years using a towel, the infant displayed both social

Figure 5. Ayumu at 10-months-old dyadically interacts with the human experimenter with a playful facial expression. (Photo courtesy The Mainichi Shimbun.)

and solitary play with it, but did not engage in reciprocal exchange with us. In another case, we tried to reciprocate with the infant using a ball but she "stole" the ball and started solitary play with it. She did give it back to the experimenter but only when the ball was exchanged for food (cf. Tomonaga & Hayashi, 2003). The chimpanzee infants never displayed "object showing" or "object giving," indicative of referential communication in a triadic relationship in human infants, as was found in an 18-month-old nursery-raised chimpanzee by Russell et al. (1997). Okamoto et al. (2004) also report that the infant did not look at the experimenter's face again having followed the human's pointing and looked back, which is one of the common behaviors of shared attention in human infants (e.g., Carpenter et al., 1998).

In addition to these naturalistic observations, we also conducted more controlled observations (Kosugi, Murai, Tomonaga, Tanaka, Ishida, & Itakura, 2003). We presented a novel animate-like object (a remote-controlled toy) to the mother-infant pairs when the infants were 1 and 2 years olds and observed the mother-infant interactions. Initially, the infants showed some

Figure 6. Joint engagement in a triadic situation. Cleo (infant, 1 year old) manipulated the novel object (model car) held and manipulated by her mother.

"fearful" responses toward this novel object, such as withdrawing from the object and hiding themselves behind their mothers. When the infants manipulated the object, they always kept their unoccupied hand on the mother's body. After watching the mother manipulate the object, they often tried to touch it, and the mother never refused this kind of approach for searching. Such triadic interaction or "shared (joint) engagement" was frequently observed both when the infants were 1 and 2 years old (Figure 6). However, when the infant manipulated the object, she seldom looked back to her mother, showed the object to her, or gave it to her. Similarly, the mothers did not display such showing or giving behaviors. These results suggest that the mother-infant interactions with an object were not based on shared attention, which may imply that the chimpanzee mother-infant pairs interacted without referential triadic relationships. However, there might be precursors for triadic interactions in chimpanzees. As described above, the infant chimpanzees showed fearful responses toward novel animate-like objects at first, and they did not manipulate them by themselves. Only after they had seen the mother manipulate the object or had participated in shared engagement did they actively try to manipulate it by themselves. This behavior can be interpreted as one type of "social referencing" (e.g., Feinman, 1982; Sorce, Emde, Campos, & Klinnert, 1985), that is, the infant obtained some information concerning the ambiguous object through watching and joining in on the manipulation of it by the mother.

At present, we have not observed complex triadic exchanges among the mother-infant chimpanzees and objects which are based on "shared attention" or "reciprocity." It is still unclear as to whether this is a cognitive constraint or if this ability will emerge as the chimpanzees age. To address this question, we need to continue longitudinal observations and experiments.

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