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Development of Mentalizing and Communication: From Viewpoint of Developmental Cybernetics and Developmental Cognitive Neuroscience

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SUMMARY The ability to mentalize is essential for human socialization. Such ability is strongly related to communication. In this paper, I discuss the development of mentalizing and communication from the perspectives of a new idea, *Developmental Cybernetics*, and developmental cognitive neuroscience. Children only attributed intention to a robot when they saw it behaving as a human and displaying social signals such as eye gaze. The emergence of powerful new methods and tools, such as neuroimaging, now allows questions about mentalizing to resolved more directly than before.
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1. Introduction

For human infants, agents — defined as other humans — are the fundamental units of their social world. Agents provide very special stimuli to infants. Researchers of object-person differentiation have proposed a set of rules that infants probably use during their interaction with people as opposed to objects. For example, Premack suggested that infants perceive people as perceptual events that are both self-propelled and goal-directed objects. In such cases, adults also perceive people as agents with intention [1]. Spelke, Phillips, and Woodward described an infant's concept of a human as follows: "Three aspects of human interactions that are accessible in principle to young infants are contingency (humans react to one another), reciprocity (humans respond in kind to one to another's actions), and communication (humans supply one another with information) [2]." They suggested that infants interpret an object's movement with these three principles and the "principle of contact." To explain the contact principle, they used the habituation procedure and showed that infants tend to assume that an object, if it moves, was set in motion by a push from another object (or person). On the other hand, social agents don't require the application of an external force to move. They demonstrated such a perception of agency in 7-month-olds. Agents are not simply physical objects to which new properties have been added. On the contrary, they are animate entities that can move on their own, breath, eat, drink, look, and engage in actions with objects or interact with other agents [3].

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From the viewpoint of social cognitive development, Johnson [4] raised two questions: 1) when do children first attribute a mental state to others, and 2) to whom do they attribute it?

Until 10 years ago, the majority of perceptual and cognitive development studies were generated without evidence from the brain [5]. However, the recent understanding of brain function has improved significantly. Many researchers believe that the time is ripe for exploring the interface between cognitive and brain development. These techniques can be applied to increase our understanding of the development of mentalizing.

In this paper, I will review investigations into how children understand and detect both human and nonhuman agents and communicate with them. I start with a definition of mentalizing and summarize the time course of its development (Sect. 2). Then I refer to the cues used by infants to infer an agent as a social partner (Sect. 3). Using such cues reflects the ability to detect whether caretakers and social partners are attentive and responsive to their own behavior in social exchanges. This is called 'social contingency.' I introduce two studies that we have conducted on infant sensitivity toward the social contingency of their mothers and strangers. Then, we introduce a study on infant imitation of a robot's action and a false belief task with robots that propose a new research domain we call "*Developmental Cybernetics*" (Sect. 4), which studies the interaction between children and robots [6]. It has been predicted that in ordinary 21st century households, robotics technology will be as common as refrigerators and dishwashers [7]. Therefore, exploring Developmental Cybernetics is important. Finally, I will introduce two more of our own studies from the viewpoint of cognitive neuroscience (Sect. 5) and discuss the usefulness of the neurocognitive approach to understand the development of mentalizing and also introduce two studies concerned with this issue.

2. Development of Mentalizing

The term "mentalizing," used by Frith and Frith [8], has the same meaning as "theory of mind." They wrote that "'theory of mind' was not to be taken literally of course, and it certainly did not imply the possession of an explicit philosophical theory about the contents of the mind" [8]. They pointed out that theory of mind implicitly assumes that the behavior of others is determined by their desires, attitudes, and beliefs. These are not states of the world, but states of the mind. This consideration is crucial. However, in our definition, mentalizing attributes such mental states as goal-directedness, intention, and mind to humans and nonhuman agents. In other words, mentalizing is how humans perceive nonhuman agents and attribute mental states to them. Thus the development of mentalizing is the development of a mind that discovers other minds.

Frith and Frith [8] characterize four key transitions in the development of mentalizing:

a) From birth to three months, infants only a few weeks old smile and vocalize more toward humans than objects, even human-like dolls [9]. Eye movements and biological motion can grab infants' attention at an extremely early age. For example, they track the movement of self-propelled objects [10]. Three-month-olds also show more interest in the kinematic patterns of point-light displays of a human walking than in random movement [11].

b) From nine months: At this age, infants begin to engage in triadic interactions that involve the referential triangle of child, adult, and some outside entity on which they share attention. Gergely et al. (1995) defined the infant ability to reason about goals the 'principle of rationality.' [12] Infants at this age can separately represent the goals of agents and the means used to reach them. The ability to represent goals and to reason 'rationality' is considered important prerequisites of the ability to represent intentions.

c) From 18 months: This developmental watershed, which marks the end of infancy, is significant for the onset of pretend play that is considered an important precursor of the theory of mind. Leslie postulates that a child at this age has to maintain separate representations of real events from representations of thoughts that no longer need to refer to such events [13]. Reliable imitation of intentional actions performed by others, regardless of whether these actions achieve their goal, also emerges at approximately 18 months, as demonstrated by Meltzoff [14].

d) From age 5: Children from this age reliably understand false belief tasks (see Sect. 4 for details) that require the attribution of a false belief to others. After that children start to understand more difficult tasks that require the attribution of a belief about another person's beliefs: second-order tasks.

Finally, an implicit version of mentalizing, which emerges first and is concerned with desires, goals and intentions, is usually dated around 18 months [8]). However, we believe that the ability to mentalize is based on social cognition in early infancy, such as sensitivity to social contingency, face recognition, gaze following, biological motion, and so on. From the viewpoint of developmental cognitive neuroscience, clarifying the neural mechanism of mentalizing in early infancy must be the next challenge.

3. Developmental Origin of Communication

Communication in early human infants is dominated by interaction with their mothers. In such communication called 'turn taking' or 'proto conversation,' sensitivity to social contingency is one of the most important factors. Such sensitivity is the first step to understanding people as social agents. Social contingency is a useful cue deployed by infants to distinguish themselves from others. During social interaction, an infant may recognize that people are interactive if he/she reacts to them contingently; therefore, sensitivity to social contingency is an important milestone during the development of social cognition.

For the last 20 years, researchers have studied when infants begin to reveal sensitivity to social contingency and how they recognize their social partner's non-contingency. To investigate these questions, the still-face paradigm [15], [16]) and the double video (DV) live-replay paradigm have been developed and widely used [17], [18]). In the still-face paradigm, a mother becomes unresponsive (i.e., keeps her face still) after she has engaged in normal face-to-face interaction with her infant. Infants tend to respond negatively to their mother's still face. With this paradigm, Adamson and Frick concluded that infant sensitivity to social contingency appears between two to eight months.

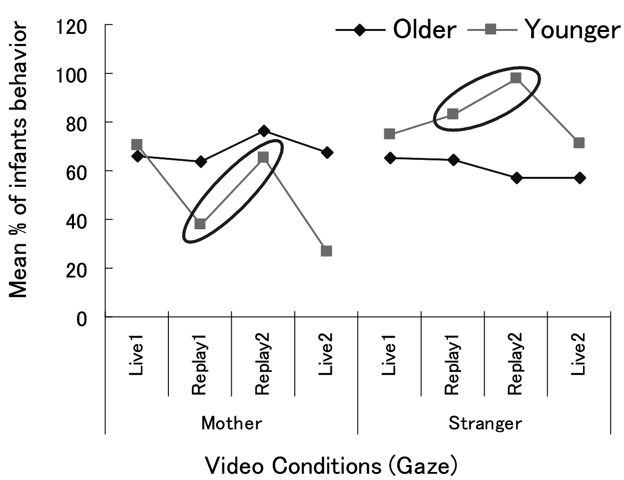
Murray and Trevarthen [17] created the DV live-replay paradigm in which a mother and her infant first interact by monitors and cameras (live condition), and then the infant is presented with a replay of the recorded mother as a non-contingent episode (replay condition). In this paradigm, an infant can continue watching his/her mother who is interacting with him/her even during the non-contingency period, so their interaction is always two-way. Murray and Trevarthen [17] found that 2-month-olds were sensitive to the social contingency of their mothers.

However, some researchers have argued that the observed behavioral changes (e.g., gaze and smile reduction) during the replay condition in infants may reflect time exceeding instead of infant sensitivity to social contingency [19]. To clarify this issue, Nadel et al. [18] used three uninterrupted sessions: Live 1, Replay, and Live 2. They found a complex V-shape pattern in the 2-month-olds' reactions. During Replay, positive indices (gazing and smiling at mother) decreased, and a negative index (frowning) increased; during Live 2 such behavioral changes disappeared. This finding supports the conclusion that 2-month-olds have developed social contingency.

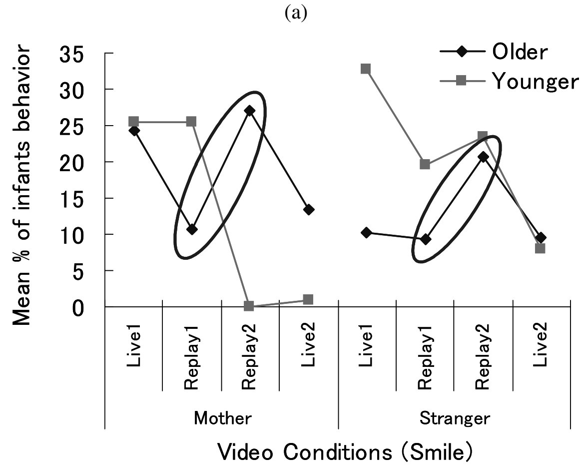
In addition, Nadel et al. [18] used a seamless edit technique between different conditions instead of including an external interrupt such as presenting infants with a hand puppet [19]) or a black screen [20]. Studies using such seamless shift techniques have indeed shown that 2-month-olds are sensitive to social contingency [20], [18]). Nevertheless, we investigated this issue since it remains unknown whether infants younger than 2-months are sensitive to maternal social contingency.

In addition, we are also interested in when infants show sensitivity to the social contingency of a stranger. Since mother is the first social partner for infants, they can discriminate mother from others at a very early age. Infants might also develop sensitivity to the contingency of their mothers at very early age as well. Previous work has shown that infants respond to the social contingency of strangers differently than from their mothers. For example, Hains and Muir [21] reported that 5-month-old infants were sensitive to a stranger's social contingency but not to their mothers.' Hains and Muir [21] and Nadel et al. [18] reasoned that this was because mother's non-contingency was not important for infants at this age because they had already developed a stable relationship with their mothers. However, since the infants had not yet developed such a good relationship with the stranger, they responded negatively to unresponsive strangers. Nevertheless, it remains unknown whether infants younger than five months are sensitive to the non-contingency of strangers. Thus, we conducted two studies to investigate the developmental changes of the social contingency of mothers and strangers in infants using a double video paradigm [22].

Infant behaviors during the first contingent (Live 1–30 seconds), non-contingent (Replay-30 seconds), and the second contingent (Live 2–30 seconds) conditions were analyzed. Given the possibility that infants may not immediately recognize their social partner's non-contingency after replay begins, each condition was divided into two periods, the first 15 seconds and the second 15 seconds.



(a)



(b)

Fig. 1 (a) Mean percentage of gazing time. (b) Mean percentage of smiling behavior.

As shown in Fig. 1, when the mother became non-contingent, younger infants increased their gazes from the first 15 seconds to the second 15 seconds of the replay condition. When the stranger became non-contingent, only older infants responded differently and increased their smiles.

These results showed that infants younger than two months were able to detect mother's non-contingency. In addition, they suggest that infants may recognize changes in mother (non-contingency) very early. Thus, the current study provides a new piece of evidence for early social cognitive development. Moreover, the current study also showed that 4-month-olds were sensitive to a stranger's social contingency and reacted emotionally to a stranger's non-contingency. They smiled to make strangers contingent again, which is an active behavior. These results imply three components in sensitivity to social contingency: detection, response, and expectancy. Among them, detection is the basis for establishing sensitivity. At an early age, these three components might be passive reactions that could develop into active responses with age. In addition, certain social tools might assist such transition as well.

4. Developmental Cybernetics

In this section, we introduce an exciting new research field in the development of mentalizing called '*Developmental cybernetics*.' In the future robots will not only perform household chores but also serve as caregivers and educators to children. To date, no scientific evidence has ascertained whether children, particularly younger ones, will be amenable to receiving care, let alone learning, from robots as readily as from humans. Despite recent rapid growth in research on developmental cybernetics, it is entirely unknown what essential human characteristics must be built into robots to facilitate such learning.

4.1 Inference of Robot Intention

One of the earliest fundamental forms of learning from another human is imitation. Imitation begins at birth with neonates who copy adult behaviors within their innately endowed behavioral repertoire (for a review, see Meltzoff [23]). With increased age, infants begin to imitate novel behaviors performed either live or televised by adults [24], [23]. Also, they can re-enact an adult's novel behavior even after a long delay [25]. More strikingly, Meltzoff [14] demonstrated that when adults performed an action that appeared to fail to accomplish their intended goal (e.g., instead of pulling apart two halves of a dumbbell, the adults' hands slipped and the dumbbell stayed intact), 18-month-olds could "imitate" the unobserved but intended act (e.g., pulling apart the dumbbell) rather than the observed but unintended act (e.g., the slippage of the adult's hands off the ends of the dumbbell with the two halves not separated).

Similar results have been found in 15-month-olds [26]–[28]) but not in 12-month-olds [26]). Similarly, Carpenter, Akhtar, and Tomasello [29] showed that 14- to 18-month-olds were more inclined to imitate an adult's intended actions than accidental actions. These findings indicate that by the second year of life, infants do not blindly imitate the behavior of others, but rather base their imitation on their understanding of the intentions and goals of others. This development is perhaps built on another developmental milestone at around 9–12 months of age when infants begin to understand that adult behavior is goal-directed and intentional [30]–[36].

Why are human infants so inclined to copy another person's behavior to the extent that they even "imitate" intended but unconsummated acts? Meltzoff [23]) proposed a "like me" hypothesis whose central tenet is that infants are innately endowed with the ability to see correspondence between the actions of others and those performed by their own body. With experience, infants learn to map their own and failed actions with their internal mental states. Such innate capacity to construe others' actions as "me relevant" coupled with an acquired understanding of their own mental state allows infants to crack the problem of other minds. They use their own intentional actions as a framework for interpreting the intentional actions of others. As a result, they can selectively imitate another's intended (but not unintended) actions. The existing developmental evidence of infant imitation involving humans as models is largely consistent with the "like me" hypothesis. It is also consistent with evidence that infants do not produce the target act when a mechanical device's behavior failed to complete an action (e.g., pulling the dumbbell apart; Meltzoff [14]). This inanimate device did not look at the human or interact with the target in a human fashion, either of which might have been sufficient to avoid triggering the "like me" interpretive framework.

What are the basic characteristics of an agent that enable infants to make "me relevant" mapping, infer the agent's goals, and thus imitate the agent's intended but unconsummated actions? One possibility is that such an agent must share human morphological characteristics. This suggestion seems reasonable given the evidence that person recognition in general and face recognition in particular begin in early infancy and develop rapidly [37], [38]). The ability to recognize and interpret faces can in theory serve as an essential enabling factor for infants to carry out such "like me" mapping and thus successfully imitate intentional and goal-directed actions.

However, Johnson et al. [4], [39]) suggested that infant recognition of intentional agents is not necessarily isomorphic with person recognition but rather based on a set of non-arbitrary object recognition cues. Johnson et al. [28] showed that a novel orangutan-like object (with eyes and nose but no mouth) that appeared to be self-propelled and interacted with infants contingently led 15-month-olds to imitate its unconsummated acts. Further, infants also displayed significantly more communicative behaviors toward the orangutan-like object than another, physically similar but faceless and inanimate object.

Johnson et al.'s [28] results clearly indicate that full-fledged human morphological characteristics are not necessary to engender imitation of intentional acts in infants. However, it is unclear whether infant imitation of intentional acts is engendered by the behavioral similarities between humans and the orangutan-like object (e.g., self-propelled and contingent movements) or the morphological similarities between the two (particularly their eyes). For example, the infants might have attributed intentions to the object due to its eyes. Indeed, infants at birth are already sensitive to stimuli containing eyes [40]. With increasing age, they increasingly treat objects with eyes substantially different from those without [41]. Furthermore, before they could imitate the intended but unconsummated acts, they already were able to use another's eye gazes to infer mental states [42]. Thus, perhaps the presence of a pair of eyes alone is sufficient for infants to "imitate" an agent's intentional acts. Alternatively, the presence of eyes must be coupled with certain contingent and meaningful actions to ensure the imitation of intentional acts. The present study tested these possibilities.

Itakura, Ishida, Kanda, Shimada, Ishiguro, and Lee (in press) [6] modified Meltzoff's [14] paradigm. Instead of using human adults, a robot named Robovie with eyes and mechanical arms served as a model (see Fig. 2). Robovie was developed at the Advanced Telecommunications Research Institute International, Intelligence Robotics and Communication Laboratory in Japan.

As human models in Meltzoff [14], the robot performed novel actions either successfully or unsuccessfully, and its behavior was video-taped and presented on a television monitor to children between 24 and 35 months of age. We chose this age range because existing studies [26], [28], [14]) have shown that by two years of age, children can successfully imitate adult's intended but unconsummated actions. In the *Eye Contact Condition*, both before and after performing a novel action, the robot made eye contact with a human adult, who was also present throughout the video presentation. In the No Eye Contact Condition, although the human adult was present and behaved exactly as he did in the Eye Contact Condition, the robot did not make eye contact with him. Thus, in the Eye Contact and No Eye Contact conditions, eyes were present. If the presence of eyes alone is sufficient, children would correctly imitate both the successful and unsuccessful acts performed by the robot in both conditions. Otherwise, children would successfully imitate the unconsummated acts in the Eye Contact Condition but not in the No Eye Contact Condition.

Modeled after Meltzoff [14], three sets of objects were used: a dumbbell, a cup and beads, and a peg with an elastic band. Robovie was controlled based on the type of action trials. In the Successful Demonstration condition, Robovie pulled the dumbbell apart, put the beads into the cup, and hung the elastic band on the peg. In the Unsuc-

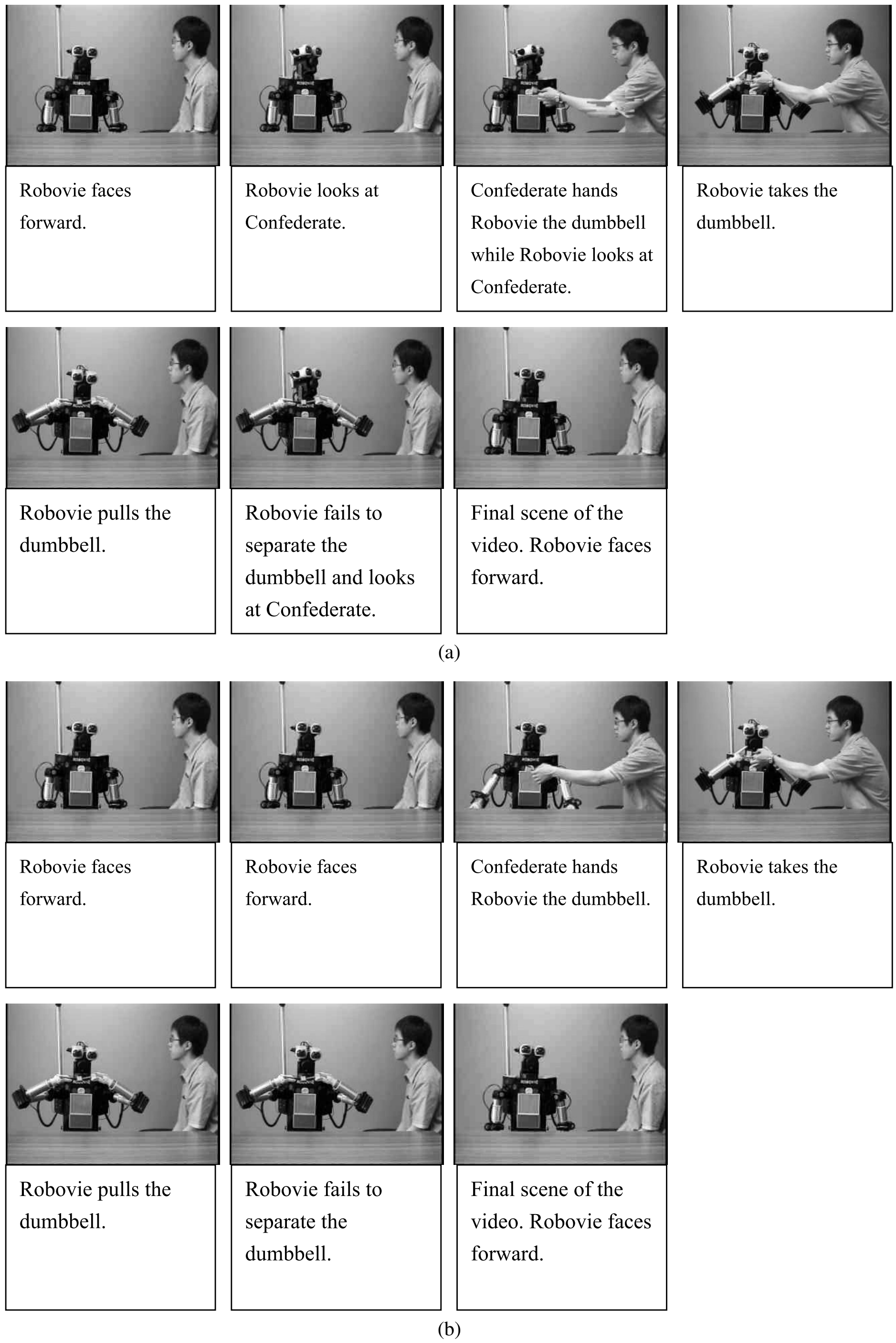


Fig. 2 (a) Robovie failed to pull the dumbbell apart in the unsuccessful demonstration + eye contact condition. (b) Robovie failed to pull the dumbbell apart in the unsuccessful demonstration + no eye contract condition.

cessful Demonstration condition, Robovie tried to pull the dumbbell apart, but failed. It tried to put the beads into the cup, but they dropped outside the cup. Robovie also tried to hang the elastic band on the peg, but it fell on the table.

The groups of children were divided into five conditions: Successful Demonstration + Eye Contact, Successful Demonstration + No Eye Contact, Unsuccessful Demonstration + Eye Contact, and Unsuccessful Demonstration + No Eye Contact, and a baseline condition in which children were simply given one of the objects to manipulate. Children were coded as having produced the target action if they showed such behavior. The results are shown in Fig. 3.

The results in the Successful Demonstration Conditions showed that young children imitated successful actions

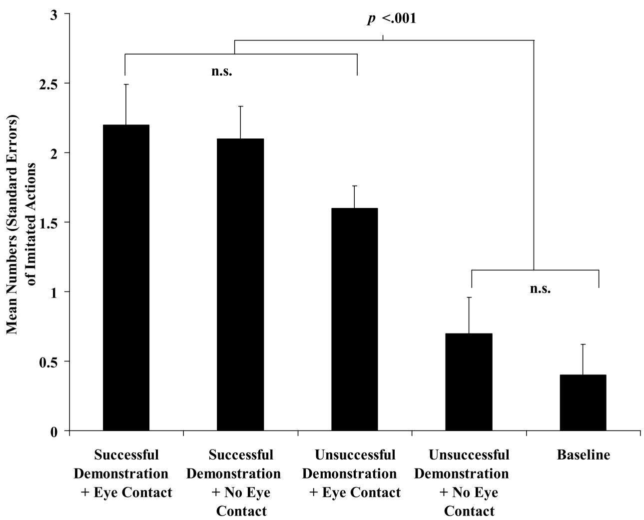


Fig. 3 Mean (standard error) number of imitated actions for each condition. n. s.: No significant.

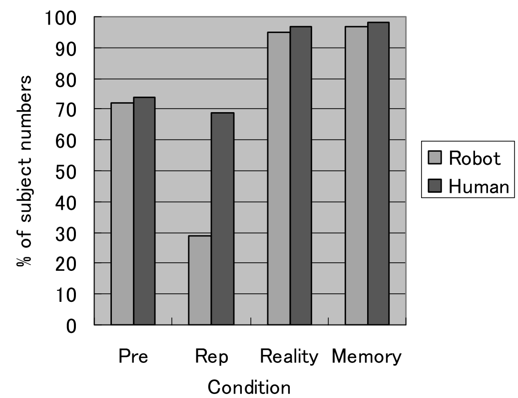


Fig. 4 Percentage of subject number. Pre: Prediction task; Rep: Representation task; Reality: Reality task; Memory: Memory task.

regardless whether the robot made eye contact with a human. In the Unsuccessful Demonstration Condition, however, children only completed the unobserved but intended action when the robot made eye contact with the human.

There are two main findings in this study. First, young children imitate a nonhuman agent's action. Second, an eye must be coupled with interactive activities with another human to complete the intentional actions. These findings will help robotic scientists design robots that not only mimic human morphologies and biomechanical movements but also convey a sense of "intentionality."

4.2 False Belief of a Robot

In a paper entitled 'Does the chimpanzee have a "theory of mind"?,' Premack & Woodruff [43] addressed whether a chimpanzee's mind works like a human's. However, the paper implicitly assumes that the behavior of others is determined by their desires, attitudes, and beliefs [8]. These are not states of the world, but states of the mind. However, we have not found robust evidence of the theory of mind in any nonhuman species yet. In contrast to such uncertainty about theory of mind in nonhuman species, human children clearly exhibit a complex capacity to understand the minds of others at an early point in their development.

Generally, from approximately four or five, children understand that other humans have beliefs that may differ from their own. The most common test of children's ability to explain an action with reference to another's belief is the *False Belief Task* [44]. In this study, a child is told about Maxi, whose mother places a piece of chocolate in a green cupboard. While Maxi is outside playing, the mother moves the chocolate from the green cupboard to a blue cupboard. Children are then asked to report Maxi's belief ("Where does Maxi think the chocolate is?"), to predict her action ("Where does Maxi look for the chocolate?"), or to explain the completed action ("Why did Maxi look for the chocolate in the green cupboard?"). The critical feature of the false belief task is that correct answers to all three questions require the subject to concentrate on Maxi's belief rather than the actual location of the chocolate.

In light of the previous discussion, we investigated whether young children infer a robot's mental state in a standard False Belief Task [45]. Robovie was again used, as in the study outlined in the previous section. The participants were 58 young children (27 boys, 31 girls, range = 54 to 80 months, mean = 65.4 months). We chose this age range because many studies have demonstrated that children between four and five years of age pass the *False Belief Task*. Both versions of the video stimuli were presented by video monitor. Robovie places the doll in Box A and then leaves the room. During Robovie's absence, a man removes the doll from Box A and places it in Box B. The second condition was identical except that a human, not a robot, performed the actions.

Each subject was shown these two videos and given four questions after watching them individually. The order of presentation was counterbalanced. The following four questions were asked: i) "Where will it/he look for a doll?" (Prediction task); ii) "Where does it/he think the doll is?" (Representation task); iii) "Which box has the doll?" (Reality task); and iv) Which box used to have the doll?"(Memory task). The experiment results are shown in Fig. 4.

There was no difference between the human and robot conditions in the reality and memory questions; most children correctly answered these questions. Additionally, there was also no difference in the prediction question between both conditions. However, there was a significant difference between the human and robot conditions in the representation task. These results show that while children attribute false beliefs to robots, they do not attribute *mental verbs* to them.

In this study, we provide suggestive evidence that young children discriminate between a robot and a human when the question involved such a mental verb as "think." Young children seem to have difficulty linking searching and thinking behaviors in a robot. In light of the results reported in the previous section, children apparently need to be shown the robot acting as a communicative agent to infer that it is actually 'thinking.'

5. Neural Base of Mentalizing and Communication

Not all measurements in psychology have such overt behavior as our target. Measures of underlying physiological processes can also be informative, especially in infants and young children for whom overt behaviors are often limited. Recent years have seen some exciting advances in techniques for studying the brain that allow researchers to examine not only the brain's anatomy but also its activity while people perform a variety of tasks. These techniques are applicable to social cognition or mentalizing. In this section, I review our own experiments and the most recent studies of our colleagues.

Self recognition is one crucial milestone of the sociability concerns of mentalizing. We attempted to identify the cortical region involved in self-recognition and self-evaluation with self-conscious emotions in adult subjects [46]. To increase the range of emotions accompanying self-evaluation, we used facial feedback images chosen from a video recording, some of which deviated significantly from normal images. 19 participants rated images of their own face (SELF) and those of others (OTHERS) based on how photogenic they appeared. After scanning the images, the participants rated how embarrassed they felt upon viewing each face. As the photogenic scores decreased, the embarrassment ratings dramatically increased for the participant's own face compared with those of others. The SELF versus OTHERS contrast significantly increased the activation of the right prefrontal cortex, the bilateral insular cortex, the anterior cingulate cortex, and the bilateral occipital cortex. In the right prefrontal cortex, activity in the right precentral gyrus reflected the trait of the awareness of the observable aspects of the self, providing strong evidence that the right precentral gyrus is specifically involved in self-face recognition. In contrast, activity in the anterior region, located in the right middle inferior frontal gyrus, was modulated by the extent of embarrassment, suggesting that it is engaged in self-evaluation preceded by self-face recognition based on relevance to a standard self. This study was conducted in adult subjects; however, we must collect brain activity data to consider the theoretical and logical aspects of the target issue in adults.

The direction of other's eye gaze is a crucial source of information in social interactions. Eye gaze also provides information about others' communicative intentions and future behavior (Baron-Cohen 1995) [47]. Striano et al. investigated the functional relevance of gaze cuing in infancy (Reid and Striano 2005) [48] and presented 4-month-old infants with videos of a face that was directing its eye gaze toward one of two objects. When exposed to both objects again without the face, infants looked longer at the previously uncued object, indicating that they perceived it as more novel.

Based on this study, they raised an important unaddressed question: How do infants process the relation between another person and an external object? How do they use the information provided by adult's eye gaze to guide their attention and process environmental information? Striano et al. employed an ERP approach to explore this question [49]. This paradigm allows direct investigation of the neural systems included in information processing even in the absence of overt behavior. Their study assessed how 4-month-old infants process the directedness of adult eye gaze in relation to objects in their field of view, which is the same as the face itself. They presented static photographs of faces with eye gaze averted to the left or right side. One object was presented near the face, either presented on the same side as the direction of the eye gaze or on the other side. Their prediction was as follows: infants would form a stronger memory representation for the cued objects. This would be reflected by an enhanced positive slow wave (PSW), which is probably related to stimulus updating or encoding in 4-to-6 month-olds, during the observation of stimuli depicting eye-gazed-cue objects.

The results suggest that infants differentially process whether an adult's eye gaze is directed at one object or averted from an object. PSW at frontal sites was enhanced during eye gaze directed toward an object when compared to eyes gazing away from an object. They interpreted this finding as evidence that infants form a stronger memory representation for cued compared to uncued objects.

6. Conclusion

In this paper, I discussed the development of mentalizing and communication from the perspectives of a new idea, *Developmental Cybernetics*, and developmental cognitive neuroscience. I defined the origin of the communication as 'turn taking' or 'protoconversation' between infants and others. In this situation, infants need sensitivity to social contingency to maintain such simple communication. We found that such sensitivity involved in very early infancy reflected socialization ability.

Children only attributed intention to a robot when they saw it behaving as a human and displaying such social signals as eye gaze. Children only completed the unobserved but intended action when the robot made eye contact with the human. This is essential for how children invest intention in nonhuman agents, such as robots. They must detect that the agent has a social signal dispatched by the agent and instantiate it as communicative. Such a signal does not need to be complex; a very subtle but strongly impacted one (e.g., eye gaze) is sufficient. We adults might consider social signals complicated, but they are much simpler in some contexts.

Now powerful new methods and tools have become available to cognitive neuroscience that allows questions about mentalizing to be asked more directly than before. One set of tools related to neuroimaging, the generation of "functional" maps of brain activity, is based on physiological changes. Three current techniques are readily applied to development in normal children: event related potentials (ERP), functional magnetic resonance imaging (fMRI), and near infra-red spectroscopy (NIRS). These techniques appear especially useful in infants and toddlers for whom overt behaviors are often limited.

I hope *Developmental Cybernetics* and developmental cognitive neuroscientific approaches obtain better understanding of the development of mentalizing and communication in the near future.

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