Infant Behavior & Development 42 (2016) 157–167

Contents lists available at ScienceDirect

Infant Behavior and Development

Full length article

Do infants perceive the social robot Keepon as a communicative partner?

Andreea Peca[a,*], Ramona Simut[b], Hoang-Long Cao[c], Bram Vanderborght[c]

[a] Babeş-Bolyai University, Department of Clinical Psychology and Psychotherapy, Cluj-Napoca, Romania
[b] Vrije Universiteit Brussel, Clinical and Life Span Psychology Department, Brussels, Belgium
[c] Vrije Universiteit Brussel, Robotics and Multibody Mechanics Research Group, Brussels, Belgium

ARTICLE INFO

Article history:
Received 7 April 2015
Received in revised form
27 September 2015
Accepted 3 October 2015
Available online 14 November 2015

Keywords:
Human–robot interaction
Contingency
Agency
Turn-taking
Conversation
Infants

ABSTRACT

This study investigates if infants perceive an unfamiliar agent, such as the robot Keepon, as a social agent after observing an interaction between the robot and a human adult. 23 infants, aged 9–17 month, were exposed, in a first phase, to either a contingent interaction between the active robot and an active human adult, or to an interaction between an active human adult and the non-active robot, followed by a second phase, in which infants were offered the opportunity to initiate a turn-taking interaction with Keepon.

The measured variables were: (1) the number of social initiations the infant directed toward the robot, and (2) the number of anticipatory orientations of attention to the agent that follows in the conversation. The results indicate a significant higher level of initiations in the interactive robot condition compared to the non-active robot condition, while the difference between the frequencies of anticipations of turn-taking behaviors was not significant.

1. Introduction

In the last decades, there has been an increased research interest related to the infants' attunement to their social environment and the development of the behavioral reciprocity of the infant and their primary caregiver in the first years of life. These studies have important implications for our understanding of the early social development and the development of the self. Children develop the capability for social communication through physical and social interactions with their caregivers, from the moment of birth. There is a lot of evidence that infants are capable to mimic orofacial actions at birth (Meltzoff & Moore, 1989; Nadel & Butterworth, 1999; Meltzoff, 2005), and recognize the prosodic features of their mothers' voices (DeCasper & Fifer, 1980; Fernald & Mazzie, 1991); in the first two months of life, the temporal structure of the rhythmic turn-taking originates mainly from the caregiver's reading the child's response pattern, while the child establishes eye-contact with the caregiver, along with exchanges of voice and facial expressions (Kozima & Nakagawa, 2006). At 2–3 month, infants are already aware of their mother contingent and emotional appropriate behavior and actively engage with it, according to the results obtained with the still face and the double television replay procedures (Trevarthen, 1993a; Trevarthen, 1993b; Tronick, 1989). Longitudinal studies focused on observing the transformations that appear during the first year of life indicate, at the middle of the first year, "an increased intricate, precise and selective coordination of the infant, with the mother's richly inflected, rhythmically patterned, and repetitive expressions of communication"

* Corresponding author. Tel.: +40 742019045; fax: +40 264434141.
E-mail address: andreea.peca@gmail.com (A. Peca).

http://dx.doi.org/10.1016/j.infbeh.2015.10.005
0163-6383/

(Trevarthen & Aitken, 2001). During this period, the child gradually learns to predict the caregiver's behavior, which makes the interaction more and more symmetric (Kozima & Nakagawa, 2006). By the end of the first year, before the emergence of words, the human infant can communicate efficiently by using conventional vocalizations and gestures (Trevarthen & Aitken, 2001). However, what is the role of these fine-tuned abilities to coordinate with another human being? Are these the prerequisites for more sophisticated social abilities? Meltzoff (1990), Meltzoff and Moore (1995), Meltzoff and Brooks (2001) and Meltzoff (2002a) argues that imitation is the test infants use to discriminate between an intentional and an unintentional agent. The innate equipment for imitation and imitation recognition represents a neural mechanism for recognising "congruent with me", not just "contingent on me". The temporal contingency is not a sufficient condition, the congruence is also necessary for infants to recognise the object as a "like-me" entity and attribute a "mind" to that entity. This theory has received a growing consensus from different disciplines, from evolutionary psychology to neuroscience (e.g. Gordon, 1995; Tomasello, 1999; Rizzolatti, Fogassi, & Gallese, 2002).

Developmental psychology has also addressed the issue of attributing mental states to objects.

A few studies suggest that infants attribute mental states only to humans (Field et al., 1982; Legerstee, 1991; Meltzoff, 1995, cited in Arita, Hiraki, Kanda, & Ishiguro, 2005). The results of these studies are questionable in the light of several facts: the object used in these experiments were objects for which infants had already formed expectations, the objects had few human-like features and motion (Legerstee, 1994, 1997, 2001, cited in Arita et al., 2005). On the other hand, several studies found evidence that infants attribute mental states to non-human objects that appear to interact with persons: a box-shaped machine that beeped and flashed lights, or a small fur ball that was making noises and flashed lights (Movellan et al., 1987; Johnson et al., 1999, 2001, cited in Arita et al., 2005). Another interesting study is the one of Arita et al., 2005, who used the looking-time paradigm (Legerstee, Barna, & DiAdamo, 2000) to investigate whether 10-month old, expected people to talk to a humanoid robot, obtained similar results. They found that infants only perceived the interactive robot as a communicative agent and the non-interactive robot (either active or stationary) as an object. Moreover, the results of Johnson and Shimizu (2004) suggest that by the end of the first year of life, infants have a broad and complex definition of what counts as an agent and attribute goals even to non-human and unfamiliar agents. These results imply that interactivity between humans and objects is the key factor in mental attribution.

The evidence suggesting that the congruence and contingency of actions may play an important role in the perception and attribution of intentionality, has led to a growing interest in endowing robots with the ability to imitate. One important aspect of contingency is the temporal proximity between the user's behavior and the robot's response. In natural conversation, communication partners tend to respond to each other's linguistic behavior in a time frame of approximately 200–300 ms (Sidnell & Enfield, 2012). Another important aspect refers to the synchrony between movements and sounds. When speaking to infants, parents perform movements that are in a tight temporal synchrony with the speech (Gogate, Bahrick, & Watson, 2010) and are shorter, which results in less roundness and more pauses between the individual segments (Brand et al., 2002; Rohlfing et al., 2006, cited in Fischer et al., 2013).

Movellan and Watson (2002) investigated whether infants follow the line of regard of a non-human robot with an abstract pattern that did not resemble the structure of a human face. They found that infants follow the line of regard when the robot responded contingently to different events in the external environment and to the infants' initiations. In another study, Meltzoff, Brooks, Shon, and Rao (2010) found that infants use the information derived from an entity's interactions with other agents as evidence about whether that entity is a perceiver. The infants who saw the robot interacting contingently with a human adult were more likely to follow the line of regard of the robot.

Other studies have investigated the preference infants have for a contingent or noncontingent interaction. The results of Sidner, Lee, Kidd, Lesh, and Rich (2006) suggest that participants interacted longer with a penguin-shaped robot that was producing contingent, non-verbal feedback, judging it as being more reliable and its movements more appropriate. Similar results were obtained by Kose-Bagci, Dautenhahn, Syrdalm, and Nehaniv (2010), participants showing a preference for a contingency pattern whose temporal dynamics was closer to human–human conversations.

These results have important implications for the development of the social robotics domain.

While some studies suggest that interactivity is the essential condition for the attribution of intentionality, and other studies suggest that contingency is necessary, another line of studies suggest that both the contingency and the congruence conditions should be met and that the robot should be designed in a way that allows it to be involved in "like-me" actions.

On the other hand, robots represent as "an ideal opportunity to study cognitive and social development in infants" (Scasselatti, 1998, 2000; Deák, Fasel, and Movellan, 2001). By creating robots that have different morphological characteristics and by programming them to exhibit precisely controlled contingency structures, researchers can test the strategies infants use to identify their nature and capabilities (Movellan & Watson, 2002). The questions that should be addressed in this approach are: Which are the requirements that robots should meet in order to be treated by infants as conversational agents? Is animacy a sufficient condition? Is contingency absolutely necessary? What about similarity? Do infants need similarity in order to find a correspondence between their actions and the actions of the robot?

This study aims to investigate if infants use an unknown agent, the robot Keepon, as a communicative partner after observing a brief conversation between a human adult and the robot. More specifically, our study aims to investigate if the interactivity of the robot Keepon is a sufficient condition for perceiving it as a communicative partner.