Motions of Robots Matter! The Social Effects of Idle and Meaningful Motions

Raymond H. Cuijpers(✉) and Marco A.M.H. Knops

Human Technology Interaction Group, Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands
r.h.cuijpers@tue.nl

Abstract. Humans always move, even when "doing" nothing, but robots typically remain immobile. According to the threshold model of social influence [3] people respond socially on the basis of social verification. If applied to human-robot interaction this model would predict that people increase their social responses depending on the social verification of the robot. On other hand, the media equation hypothesis [11] holds that people will automatically respond socially when interacting with artificial agents. In our study a simple joint task was used to expose our participants to different levels of social verification. Low social verification was portrayed using idle motions and high social verification was portrayed using meaningful motions. Our results indicate that social responses increase with the level of social verification in line with the threshold model of social influence.

1 Introduction

During human-robot interaction a robot typically stops moving during idle periods and the robot appears inanimate and lifeless. On the other hand, the human body never stops moving and therefore always communicates being alive. So idle movements could present a basic "illusion of life", which could help people accept the robot as a social entity [8]. Idle motions are used a lot in gaming and movie animations [5,12]. However, only few studies investigated the role of idle motions in relation to making robots more social entities. For example, [14] mimicked clerk idle movements on a robot, but the effect on social interaction was not tested.

There are two competing views about people's social responses towards artificial agents. According to the media equation hypothesis [11] humans automatically respond socially when interacting with artificial agents as long as there are some behaviours that suggest a social presence. For example, it was found among others that people rate computers more trustworthy and intelligent when the computer belonged to the same team, or when it showed an avatar's face of the same ethnicity [10]. It is suggested that people respond out of habit to mimicked social cues due to overlearning [10]. Based on this, one would expect that a robot portraying idle motions not only looks more alive but also elicits social responses. On the other hand, the threshold model of social influence [3]

A. Tapus et al. (Eds.): ICSR 2015, LNAI 9388, pp. 174–183, 2015.
DOI: 10.1007/978-3-319-25554-5_18

is based on the idea of "social verification": people verify that they are engaging in semantically meaningful communication when interacting. Two interpersonal factors are considered of special importance for verifying meaningful interaction: the behavioural realism with which social cues are portrayed, and agency, the extent to which the agent is perceived as human-like. According to this idea idle motions would not contribute to social verification, and therefore, not elicit social responses. Movements portrayed by a robot would have to be meaningful and embody social cues. Various studies have examined meaningful gestures in the field of HRI. Gaze has been demonstrated to influence the persuasiveness of a robot during a conversation [4]. Other non-verbal meaningful gestures, like hand/arm gestures, have been demonstrated to improve communication efficiency and user experience [15], and anthropomorphism [13].

In this study we investigate the social effects of idle- and meaningful motions as compared to no motions, and compare our results with two competing views of social effects in human-robot interaction: the media equation hypothesis [11] and the threshold model of social influence [3]. According to the threshold model of social influence, meaningful motions serve as semantically meaningful communication with the robot, and are perceived to have higher behavioural realism than idle motions. Therefore, they should trigger stronger social responses than idle motions. In particular, we expect that meaningful motions are perceived as more socially intelligent and more anthropomorphic than idle motions and no motions [6]. On the other hand, according to the media equation hypothesis, idle motions already elicit social responses. So in this case we expect that idle and meaningful motions are both perceived as more socially intelligent and more anthropomorphic than idle motions and no motions. Both idle motions and meaningful motions are expected to improve the perceived life-likeness of the robot compared to no motions.

2 Method

We conducted an experiment where the Nao robot (Aldebaran Robotics, France) helped participants unpack a cardboard moving box that contained 16 items. There were two main conditions: In one condition the Nao robot displayed the so-called idle motions, in the other condition the robot displayed the meaningful motions. Within the two main conditions there was a baseline no-motion condition and three motion conditions.

2.1 Participants

73 participants took part in the experiment, of which 41 were male and 31 were female (mean age 25.55, SD = 7.012, range 18 to 54). Participants were randomly assigned to one of the two experimental conditions. 40 participants had prior experience with robots, including the Nao robot, but this did not influence our results. Participants received a monetary compensation of 5 euros for participating in the experiment.

2.2 Design

The experiment was conducted using a mixed design. We used two different motion types as a between-subjects factor, which differed in terms of social verification: Meaningful and Idle motions. The Meaningful motion condition portrayed semantically meaningful communication (high social verification). The Idle motion condition portrayed interactions that are argued to only aid in the "illusion of life" (low social verification). In both groups a no-motion condition was used as a baseline. There were three meaningful movements: (1) Arm pointing, (2) Head pointing, and (3) Eye-contact. And three idle motions: (1) Posture shift/sway (2) Random head movements, and (3) Breathing motion. Each participant experienced three movement conditions (either idle or meaningful) and the baseline condition in four blocks. The baseline was always presented first, the three movement conditions were counterbalanced across subjects. Each block required the unpacking and correctly placing of four items from the moving box, after which participants were asked to fill in a questionnaire. Each block consisted of four trials resulting in a total of 16 trials per participant.

2.3 Experimental Set-up

Participants interacted with the humanoid Nao robot (Aldebaran Robotics, France). The Nao is a 58-cm tall humanoid robot, which has 25 degrees of freedom, two cameras, an inertial measurement unit, touch sensors and four microphones all enabling him to detect and interact with its surroundings. The robot was partially controlled using a Wizard-Of-Oz technique. For each of the within-subject conditions there were predetermined utterances. These utterances were randomised for each within-subject condition. The items were located in the cardboard moving box and had to be unpacked. The chosen items and item locations were chosen such that they did not cause confusion or bias of where they should be placed. We used 16 items: a white vase, green cup, yellow cup, instruction manual, white bowl, clock, candles, photo frame, telephone, fruit bowl, two glasses, power adapter, headphones, stereo cable and a remote control. The questionnaire was implemented using Macromedia's Authorware software. The experiment took place in a mimicked living room in which the Nao robot would serve as a household assistant. Figure 1 shows an overview of the robot and object locations. The room was equipped with 3 cameras, so that the experimenter could observe and control the interaction from the observation room.

2.4 Robot Motions

We used the Principles of Animation [12] as a guideline to create the idle motions that generate an "illusion of life". We chose a breathing, posture sway and gaze shift motion, primarily because of the limitations of the Nao robot. To mimic a breathing motion, the Nao robot made a slight motion with its head, shoulder joints and hip joints. The frequency of the breathing motion was constant and fixed in a pretest. The idle gaze shifts were implemented by adjusting both the

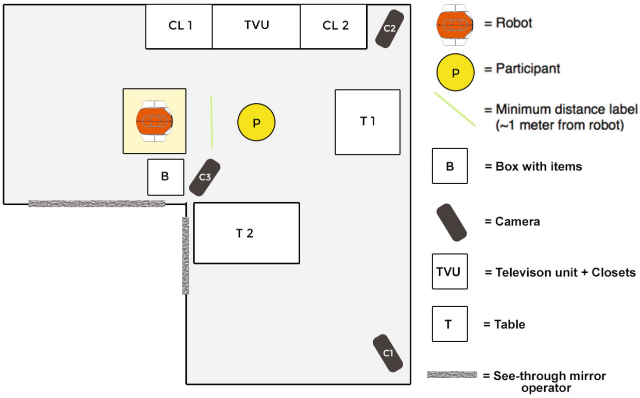

Fig. 1. A top down view of the UseLab. On the right side the different items are listed that were used during the experiment. Furthermore the minimum distance label can be seen between the Nao robot and participant.

head pitch and yaw. A total of 8 pre-recorded head motions were executed at a random time interval (between 15-22 seconds). The posture sway motions were implemented by counter-rotating the hip and ankle joints including small adjustments to the head and arm joints. A total of 8 randomised pre-recorded motions were executed at random on a certain time interval (between 20-30 seconds). The motion parameters were pretested so that the motions looked natural. We verified whether the idle motions were perceived correctly by having the participant describe which motion the robot portrayed. Out of 37 participants 86.5% perceived the posture sways correctly, 78.4% perceived the gaze shifts and 83.8% perceived the breathing motion.

The meaningful motion eye-contact/gaze was realised using a face tracking algorithm that centres the gaze of the Nao robot on the participant. During this interaction the Nao robot checks whether the participant is looking at the robot using a head pose estimation algorithm its eyes, thus creating a mutual facial gaze interaction. The arm pointing and head pointing gestures were implemented in combination with deictic expressions: gesture conveyed the lacking spatial information in the speech. For example, the robot could say "Please take the power adapter, and place it in the closet" and point to ether the left or right closet. Since there were 4 locations, 4 deictic arm gestures and 4 deictic head gestures were implemented. Out of 36 participants in the meaningful motion condition, 91.7% perceived the deictic arm pointing gesture correctly, 83.4% perceived the deictic head gesture correctly and 86.2% perceived the gaze motion correctly. The no-motion condition, which acted as a baseline throughout the experiment, was perceived correctly by 86.5% out of 73 participants.

2.5 Verbal Utterances

Each instruction given by the Nao robot had following syntax: “Please take the [object], and place it [position+location].” In the meaningful condition the two syntax components had a separate deictic gesture assigned to them. For example, the Nao robot could say “Please take the remote control” while pointing at the moving box, followed by pronouncing “and place it in the closet,” accompanied by a pointing gesture towards the closet. This was all done in a fluent manner that looked natural.

2.6 Questionnaire

The questionnaire is based on the 5-point Likert scale Godspeed questionnaire [2], which measures: anthropomorphism, animacy, likeability, perceived intelligence and perceived safety. We excluded perceived safety from the questionnaire since this was not relevant to our study, and replaced this dimension with the emotion dimension (4 questions) and the social intelligence dimension (4 questions). The former allowed us to measure the perceived emotional responsiveness of the robot. The latter enabled us to measure the social competence and social skills of the Nao robot and is based on [9].

2.7 Procedure

On arrival participants filled in the informed consent forms, and received general instructions. When there were no further questions the experiment was started from the control room. The robot introduced itself and provided a short explanation of the task. First the baseline condition with no movements was presented, in which the robot directed the participant with verbal utterances to unpack the box. The utterance consisted of two parts: the first part indicated the item (e.g., Please take the white vase) and the second part indicated where the item should be placed (e.g., and place it on the table). After placing the object the participant was required to stand in front of the Nao robot again to signal that they were ready for the next item. After placing four items in the correct location the Nao robot instructed the participant to take a seat in the chair, and fill in the questionnaire provided on the laptop. After completing the questionnaire, the participant stood in front of the Nao robot again to continue the next experimental block. This was repeated four times for a total of sixteen items. In total the participants interacted approximately 10 minutes with the Nao robot. After completing the last questionnaire the participants were debriefed about the purpose of the experiment and then thanked and paid. The experiment lasted about 30 minutes.

2.8 Data Analysis

To check the internal consistencies a reliability analysis was conducted. Cronbach’s alpha exceeded 0.7 for all dimensions of the questionnaire, indicating that the items had good consistency. We had to exclude the data of 10 participants regarding the eye-contact condition (meaningful motion condition only), because the robot lost eye-contact.

3 Results

3.1 Social Verification

To verify our hypotheses regarding the media equation hypothesis and threshold model of social influence, we compared meaningful and idle movements conditions. To remove individual differences in overall ratings we subtracted the baseline condition first, which was always presented first. The result is shown in Figure 2. It is clear that Likeability, Perceived intelligence, social intelligence and emotion scored higher when the robot displayed meaningful motions than when it displayed idle motions.

A MANOVA analysis with the questionnaire dimensions as dependent variables and social verification as factor confirmed a statistically significant main effect of social verification, $F(6, 202) = 4.38, p < .01, \eta^2 = 0.12$. Participants rate the Likeability dimension higher ($F(1, 209) = 7.17, p < 0.01, \eta^2 = 0.03$) for conditions which portrayed meaningful motions (M = 0.28, SD = 0.85) than for idle motions (M = -0.02, SD = 0.79). Perceived Intelligence is higher ($F(1, 209) = 13.64, p < 0.01, \eta^2 = 0.06$) for conditions which portrayed meaningful motions (M = 0.37, SD = 0.78) than for idle motions (M = -0.03, SD = 0.79).

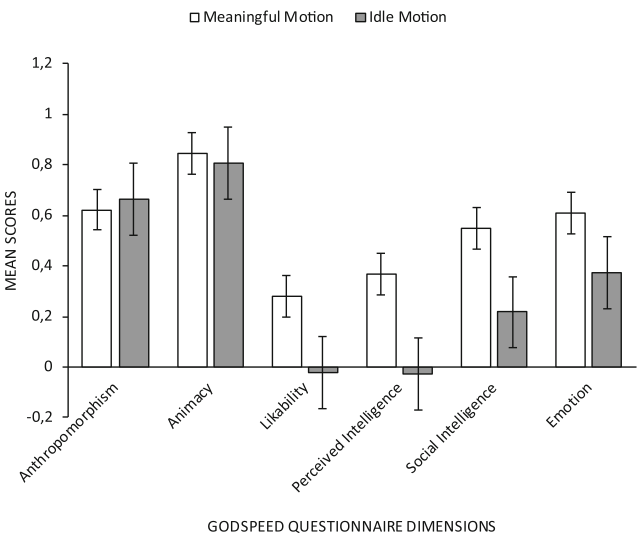

Fig. 2. Mean Likert scores for the meaningful motion and idle motion conditions after subtracting the baseline. The errors bars show the standard error for the mean at ±1 SE.

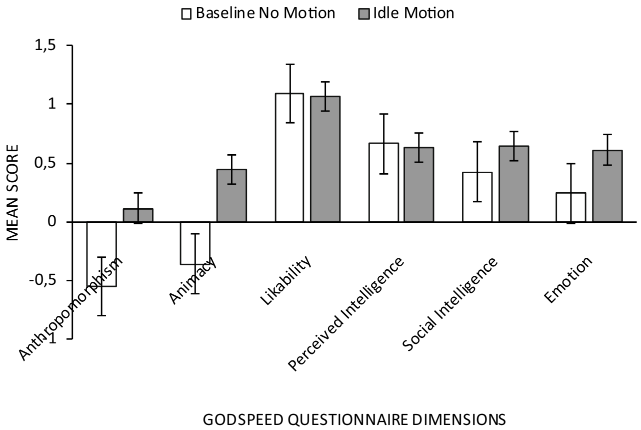

Fig. 3. Mean Likert scores for the idle motion condition and the baseline no-motion condition. The errors bars show the standard error for the mean at ±1 SE.

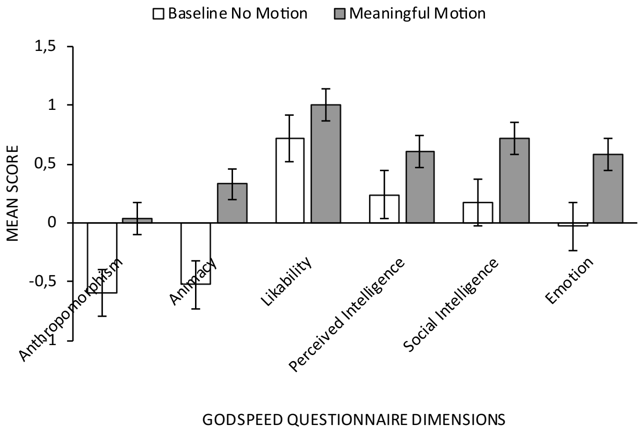

Fig. 4. Mean Likert scores for the baseline no-motion condition and the meaningful motion condition. The errors bars show the standard error for the mean at ±1 SE.

Table 1. Overview of the results of the ANOVA testing the within-subject effect of meaningful motions compared to the baseline condition.

	No motion (n=36)		Motion (n=105)				
Questionnaire Dimension	M	SD	M	SD	$F(1, 139)$	p	η^2
Anthropomorphism	-0.59	0.74	0.03	0.93	13.25	< 0.001	0.09
Animacy	-0.51	0.87	0.33	0.82	27.44	0.01	0.17
Likability	0.71	0.88	1.0	0.85	2.89	0.09	0.02
Perceived Intelligence	0.23	0.89	0.6	0.78	5.82	0.02	0.04
Social Intelligence	0.17	0.89	0.72	0.65	15.42	< 0.001	0.1
Emotion	-0.03	0.7	0.58	0.74	18.45	< 0.001	0.12

Likewise, social intelligence is higher ($F(1, 209) = 10.11, p < 0.01, \eta^2 = 0.05$) for conditions which portrayed meaningful motions (M = 0.54, SD = 0.65) than for idle motions (M = 0.22, SD = 0.81) and, finally, emotion is higher ($F(1, 209) = 4.76, p = 0.02, \eta^2 = 0.02$) for conditions which portrayed meaningful motions (M = 0.61, SD = 0.74) than for idle motions (M = 0.37, SD = 0.83). The anthropomorphism dimension ($F(1, 209) = 0.094, p = 0.76$) and the animacy dimension were not rated significantly different between motion conditions ($F(1, 209) = 0.113, p = 0.74$).

3.2 Effect of Motion

To determine the effect of motion we compared the different motion conditions to the no motion (baseline) conditions separately for idle motions and meaningful motions. The latter is necessary because the robot displayed a different set of motions in the idle and meaningful motion conditions. The result is shown in Figure 3 for idle motions and in Figure 4 for meaningful motions. In the idle motion condition a positive effect of motion on anthropomorphism, animacy, social intelligence and emotion is visible. To test the significance, we conducted a MANOVA analysis with questionnaire dimensions as dependent variable and idle motion (idle motion, no-motion) as a factor. We found a significant main effect of motion ($F(6, 134) = 8.911, p < 0.01, \eta^2 = 0.29$). Participants rated the anthropomorphism dimension significantly higher ($F(1, 139) = 13.33, p < 0.001, \eta^2 = 0.09$) for conditions which portrayed motion (M = 0.11, SD = 0.95) than for the baseline condition without motion (M = -0.55, SD = 0.96); animacy was rated significantly higher ($F(1, 139) = 23.14, p < 0.001, \eta^2 = 0.14$) by participants for the idle motion condition (M = 0.45, SD = 0.84) than for the baseline condition without motion (M = -0.36, SD = 0.97); emotion was significantly higher ($F(1, 139) = 5.41, p = 0.02, \eta^2 = 0.04$) for conditions which portrayed motion (M = 0.61, SD = 0.83) than for the baseline condition without motion (M = 0.24, SD = 0.84). The other Godspeed questionnaire dimensions did not differ significantly compared to the baseline no-motion condition (likeability: $p = 0.88$; perceived intelligence: $p = 0.83$; social intelligence: $p = 0.16$).

We did the same analysis for the meaningful motion condition, but now with meaningful motion (meaningful motion, no-motion) as a factor. Again we found a significant main effect of motion ($F(6, 134) = 7.65, p < 0.01, \eta^2 = 0.26$).

In the meaningful motion condition, participants rated all dimensions higher for a robot showing motion than for not showing motion (see Figure 4). We found significant effects for anthropomorphism, animace, perceived intelligence, social intelligence and emotion, but not for likeability (see Table 1).

4 Discussion and Conclusions

4.1 Social Verification

We expected that participants' social responses would be higher for the meaningful motions compared to the idle motions. Results indicated that participants rated the Nao robot significantly more positive in the meaningful motion condition i.e., the robot was seen as friendlier, more intelligent, empathic and helpful compared to the idle motion condition. We can thus conclude that we found support for the threshold model of social influence. Our results indicate that participants perceived the robot with higher social intelligence and perceived intelligence when the robot portrayed meaningful motions compared to idle motions. Thus, the robot portraying meaningful motions is perceived as more socially competent and skilled. This also confirms that when the robot portrayed meaningful motions the participants perceived the interaction as semantically meaningful. As suggested in [6] we did not find evidence that social intelligence increases the level of anthropomorphism, i.e. anthropomorphism was rated the same for idle and meaningful motions.

4.2 Effect of Motion

We also investigated how humans perceive different idle motions portrayed by a robot. Our results indicated that participants perceived the robot portraying idle motions as more human-like, alive and empathic compared to the robot with no motion. These results are in line with [7] who concluded that humans automatically ascribe human traits to a robot when the robot portrays human behaviour.

As a result, the robot portraying idle motions was also perceived by participants as more empathic, or emotionally expressive compared to the no-motion robot. It was assumed that idle motions would not add to the expression of a character [8]. However, our research demonstrates that by having robots portraying idle motions, people will attribute intentions to the robot. In fact, participants sometimes remarked that the robot seemed bored or nervous during the idle motion condition. This is a further indication that participants anthropomorphised the robot when portraying idle motions. However, idle motions remain low in social verification, because participants did not perceive the robot portraying idle motions as more intelligent or more socially capable than the robot portraying no motion.

Overall, people ascribed human qualities to a robot that portrays idle motions. It does not seem to matter which idle motions are portrayed by a robot: as long as the robot makes some motions, humans will perceive the robot as more human-like and alive, albeit not more intelligent. Only when the robot portrayed meaningful motions, the robot was perceived as more socially competent and intelligent. We can thus confirm that the meaningful motions are indeed contributing in a semantically meaningful manner to social verification.

References

1. Bartneck, C., Rosalia, C., Menges, R., Deckers, I.: Robot abuse – a limitation of the media equation. In: Proceedings of the Interact 2005 Workshop on Agent Abuse (2005)

2. Bartneck, C., Kulić, D., Croft, E., Zoghbi, S.: Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. International Journal of Social Robotics **1**(1), 71–81 (2009)
3. Blascovich, J.: A theoretical model of social influence for increasing the utility of collaborative virtual environments. In: Proceedings of the 4th international Conference on Collaborative Virtual Environments, pp. 25–30 (2002)
4. Chidambaram, V., Chiang, Y. H., Mutlu, B.: Designing persuasive robots: how robots might persuade people using vocal and nonverbal cues. In: Proceedings of the Seventh Annual ACM/IEEE International Conference on Human-Robot Interaction, pp. 293–300 (2012)
5. Egges, A., Molet, T., Magnenat-Thalmann, N.: Personalised real-time idle motion synthesis. In: Proceedings of the 12th Pacific Conference on Computer Graphics and Applications (PG 2004), pp. 121–30 (2004). doi:10.1109/PCCGA.2004.1348342
6. Epley, N., Waytz, A., Cacioppo, J.: On seeing human: a three-factor theory of anthropomorphism. Psychological Review **114**(4), 864 (2007)
7. Gazzola, V., Rizzolatti, G., Wicker, B., Keysers, C.: The anthropomorphic brain: the mirror neuron system responds to human and robotic actions. Neuroimage **35**(4), 1674–1684 (2007)
8. Jung, J., Kanda, T., Kim, M.: Guidelines for contextual motion design of a humanoid robot. International Journal of Social Robotics **5**(2), 153–169 (2013)
9. Martínez-Miranda, J., Aldea, A.: Emotions in human and artificial intelligence. Computers in Human Behavior **21**(2), 323–341 (2005)
10. Nass, C., Moon, Y.: Machines and mindlessness: Social responses to computers. Journal of Social Issues **56**(1), 81–103 (2000)
11. Reeves, B., Nass, C.: How People Treat Computers, Television, and New Media Like Real People and Places. Cambridge University Press (1996)
12. Ribeiro, T., Paiva, A.: The illusion of robotic life: principles and practices of animation for robots. In: Proceedings of the Seventh Annual ACM/IEEE International Conference on Human-Robot Interaction, pp. 383–390 (2012)
13. Kopp, S., Joublin, F., Salem, M., Eyssel, F., Rohlfing, K.: Effects of gesture on the perception of psychological anthropomorphism: a case study with a humanoid robot. In: Kanda, T., Evers, V., Mutlu, B., Ham, J., Bartneck, C. (eds.) ICSR 2011. LNCS, vol. 7072, pp. 31–41. Springer, Heidelberg (2011)
14. Song, H., Min Joong, K., Jeong, S.-H., Hyen-Jeong, S., Dong-Soo K.: (2009). Design of Idle motions for service robot via video ethnography. In: Proceedings of the 18th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN 2009), pp. 195–99. doi:10.1109/ROMAN.2009.5326062
15. Torta, E., van Heumen, J., Cuijpers, R.H., Juola, J.F.: How can a robot attract the attention of its human partner? a comparative study over different modalities for attracting attention. In: Ge, S.S., Khatib, O., Cabibihan, J.-J., Simmons, R., Williams, M.-A. (eds.) ICSR 2012. LNCS, vol. 7621, pp. 288–297. Springer, Heidelberg (2012)
16. Tourangeau, R., Couper, M.P., Steiger, D.M.: Humanizing self-administered surveys: Experiments on social presence in Web and IVR surveys. Computers in Human Behavior **19**(1), 1–24 (2003)
17. Yamaoka, F., Kanda, T., Ishiguro, H., Hagita, N.: "Lifelike" behaviour of communication robots based on developmental psychology findings. In: 2005 5th IEEE-RAS International Conference on Humanoid Robots, pp. 406–411 (2005)