Laughter in Social Robotics – no laughing matter

Christian Becker-Asano Hiroshi Ishiguro
becker-asano@atr.jp ishiguro@ams.eng.osaka-u.ac.jp
Advanced Telecommunications Research Institute International
Intelligent Robotics and Communications Laboratories
2-2-2 Hikaridai, Keihanna Science City, 619-0288 Kyoto, Japan

Abstract

In this paper we describe our work in progress on investigating an understudied aspect of social interaction, namely laughter. In social interaction between humans laughter occurs in a variety of contexts featuring diverse meanings and connotations. Thus, we started to investigate the usefulness of this auditory and behavioral signal applied to social robotics. We first report on results of two surveys conducted to assess the subjectively evaluated naturalness of different types of laughter applied to two humanoid robots. Then we describe the effects of laughter when combined with an android's motion and presented to uninformed participants, during playful interaction with another human. In essence, we learned that the social effect of laughter heavily depends on at least the following three factors: First, the situational context, which is not only determined by the task at hand, but also by linguistic content as well as non-verbal expressions; second, the type and quality of laughter synthesis in combination with an artificial laugher's outer appearance; and third, the interaction dynamics, which is partly depending on a perceiver's gender, personality, and cultural as well as educational background.

Keywords: Affective Computing, Natural Interaction, Laughter, Social Robotics.

1 Introduction and motivation

Researchers in the field of Affective Computing (Picard R. W., 1997) believe that human-machine interaction will benefit from a machine's ability to recognize, express, model, communicate, and respond to emotion (e.g. (Picard R. , 2003), (Elliott, 1992), (Breazeal, 2003), (Becker, Kopp, & Wachsmuth, 2007)). Although until now no general definition of "emotion" is agreed upon (Sloman, 1999) (and probably will never be) and the usefulness of the term Affective Computing itself can be challenged (Hollnagel, 2003), computational research on Affect keeps being motivated as long as psychological (e.g. (Zajonc, 1980), (Scherer K. R., 2005)) and neuro-biological findings (e.g. (LeDoux, 2000), (Bechara, Damasio, & Damasio, 2000)) suggest an interplay of two separate components in humans: cognition and emotion. In line with these findings the first author developed the WASABI affect simulation architecture (Becker-Asano, 2008), which not only improved the naturalness of human-computer interaction, but also helps in theory construction itself.

For a (virtual or robotic) agent to appear emotional it is inevitable to design for its emotional expressivity (Dautenhahn, Nourbakhsh, & Fong, 2003). This is rather easily realized for virtual characters (Vinayagamoorthy, et al., 2006), but much more difficult in case of social robots. Either the design itself is aimed at affective expressivity as, e.g., in case of "Kismet" (Breazeal, 2003), "eMuu" (Bartneck, 2002), or "WE-4RII" (Zecca, et al., 2004), or a robot's expressive abilities at hand have to be exploited effectively. Naturally, facial expressions are the prime target when robotics researchers want to let their robot's express emotions. This approach—as reasonable as it is—is very challenging to realize properly, because humans are easily irritated by the tiniest irregularities perceived in someone else's facial movements. Therefore, it might be better to investigate other means to express emotions first, such as body movement or para-verbal expressions, e.g. laughter.

Laughter in humans serves a socio-emotional function (Provine, 2005) and two major kinds of laughter can be distinguished, namely, aversive and friendly laughter (Grammer & Eibl-Eibesfeldt, 1990). Aversive laughter is also referred to as self-generated and emotionless "Non-Duchenne" laughter (Gervais & Wilson, 2005) and can be linguistically described as "laughing at someone". Accordingly, "emotionless" does only refer to the sender's lack of emotion, but this laughter indeed might give rise to (most likely negative) emotions in the recipient, who is being laughed at. Friendly laughter, on the contrary, (linguistically circumscribed as “laughing with someone”) is characterized as stimulus-driven and emotional valenced “Duchenne” laughter (Gervais & Wilson, 2005). This positively valenced laughter can either invite the recipient to laugh as well, or it might have been elicited by another one’s laughter itself. Based on this distinction it might be necessary to avoid a human's interpretation of a robot's laughter as negative, i.e. aversive, in the aim to establish positive human-robot relationships. Results of an empirical study, however, show that in certain situational contexts the expression of negative emotions can be beneficial for human-computer interaction (Becker, Prendinger, Ishizuka, & Wachsmuth, 2005) as well.

The acoustic properties of laughter have been found to be very complex and irregular (Kipper & Todt, 2001). Furthermore, the frequency of laughter varies a lot between people (Laskowski & Burger, 2007) and laughter can be evoked by very different actions such as direct tactile interaction (i.e. tickling), automatic response to other people’s laughter, or highly cognition-based understanding of verbal humor (Panksepp, 2000). Within this context another danger lies in unwittingly fueling the impression of a childish robot, because laughter is considered inappropriate in certain situational contexts (Panksepp, 2000), which might be very difficult to detect automatically. Gender-related differences also play a role in the occurrence of laughter (Grammer, 1990), because women behave differently from men when laughing in opposite-sex encounters. People even change their communication strategies depending on the interlocutor’s sex and their interest in that person.

Thus, as soon as we build humanoid robots capable of producing acoustic laughter, a number of interesting questions arise: What effect does the interaction of a robot’s appearance with its laughter have on the judged gender? How much does the situational context, the robot’s movements, its appearance, influence the perceived naturalness of its laughter? How can the robot autonomously decide, when (not) to laugh? And last but not least: How can laughter be seamlessly integrated into speech synthesis and combined with real-time behavior generation?

The remainder of this paper is structured as follows. In the following section we discuss work related to research on laughter, before we give an outline of our research directions in Section 3. Section 4 first introduces an online survey and then presents and discusses its results. In Section 5 we consider the effects of an android’s laughter and present an empirical study, in which our android robot Geminoid HI-1 started laughing unexpectedly during a game. The final section we draw conclusions, which can guide future research on laughter in social interaction with humans and humanoids.

2 RELATED WORK

Scherer (Scherer K. , 1994) claims that laughter belongs to the class of so-called “raw affect bursts”, in which facial and vocal expression of emotion combine. For a special type of raw affect burst, described as “contempt laughter”, (Schröder, 2003) reports an auditory recognition rate of 77%. In general terms, “raw affect bursts” are less conventionalized and less symbolic than “affect emblems” (Scherer K. , 1994). The latter consist of a certain verbal content and (Shiwa, Kanda, Imai, Ishiguro, & Hagita, 2008) could already show that the humanoid robot “Robovie-II” was forgiven a slow response time, when it made use of “conversational fillers” such as the Japanese expression “etto” (resembling something similar to “well...” or “uh...” in English). In (Cowley, 2008) it is suggested to let Robovie laugh in interaction with children and Cowley believes that this kind of simple affective vocal feedback could be used to “simulate functional co-ordination”. This co-action in turn could be the basis for learning that eventually might lead to “symbol grounding” – a prerequisite for Robovie to acquire a sense of meaning and value.

Two Robovies successfully evoked laughter in a setup of a Japanese kind of stand-up comedy. Notably, they enacted more laughter in human observers than a comparable performance by human actors (Hayashi, Kanda, Miyashita, Ishiguro, & Hagita, 2008) without the need to produce laughter themselves. For a virtual agent some “affective sounds” have been used to improve affective interaction (Prendinger, Becker, & Ishizuka, 2006), but to the best of our knowledge, the use of laughter in robots or virtual agents as a powerful, para-verbal, social signal has not yet been investigated systematically.

3 OUTLINE OF RESEARCH DIRECTIONS

In the aim to integrate laughter in social robotics the following research questions have to be addressed:

1. Laughter synthesis:
    a. Is there any kind of laughter judged as most natural for social robots in general, or what kind of interaction effect exists between a robot’s appearance (in terms of design parameters) and its expected type/quality of laughter?

    b. How much care needs to be taken when combining text synthesis with laughter? Is it sufficient to simply plug pre-recorded laughter into synthesized verbal content?
2. Laughter, situational context & behavior generation:
    a. Assuming that we know how to synthesize ‘natural’ auditory laughter, does a robot’s body movement change the subjective impression of that laughter?
    b. How much does the situational context influence the interpretation of a laughing robot’s intention?
3. Interpersonal & intercultural differences in laughter production and perception:
    a. Is there any systematic connection between cultural background, gender, personality, or current internal state (e.g. mood, emotion) of a person and his or her way to produce laughter?
    b. Do people of different cultural background perceive and interpret laughter (of a robot) differently?

With our online survey (reported on in the following section) we focused on the first and third aspect of laughter research. We designed for a specific situational context, i.e. that of a robot laughing in response to a joke, and let our participants from around the world judge the perceived naturalness of six different types of laughter produced by two different versions of the Robovie series.

The Geminoid study was conducted to gain empirical data on the second area of laughter research. Here we set up a playful direct interaction between the participant and a confederate and programmed Geminoid such that it passively took part in this interaction as an experimenter. In result, we could study the effect of unexpected laughter in combination with eye gaze and whole body movement of Geminoid (see Section 5).

4 NATURALNESS OF LAUGHTER FOR HUMANOIDS AND INTERCULTURAL DIFFERENCES

In our first approach to study laughter with social robots, we decided to establish a precise situational context in which our robots started to laugh. We told the observers that the robots would be laughing in response to a joke, because in such a non-serious situation laughter is naturally occurring and a misinterpretation of the robot's laughter as negative, aversive laughter is avoided. Thus, we focused on what kind of recorded human laughter would be judged as most natural when being produced by the two humanoid robots “Robovie-II” (Kanda, Ishiguro, Ono, Imai, & Mase, 2002) and “Robovie-R2” (Yoshikawa, Shinozawa, Ishiguro, Hagita, & Miyamoto, 2006) (cp. Figure 1). We used these two different Robovie versions in order to check for a possible interaction effect between the robot's outer appearance and the perceived naturalness of its laughter.

Figure 1: Robovie-II with its initial posture and during laughter (left, second from left); Robovie-R2 with its initial posture and during laughter (third from left, right)

4.1 PROCEDURE

This video-based survey was conducted online allowing people from around the world to take part. Accordingly, at first they could choose among German, English, or Japanese language, before they were given explanations about the purpose of the study and its interface (cp. Figure 2). They could also read the complete joke, in response to which the robot would laugh later on, and they could listen to the last sentence of that joke, if they liked. This last sentence was always played in the beginning of each video to establish the situational context in the minds of the participants. After some personal data was acquired and a validation via email to avoid multiple participations was successful, participants were shown the interface depicted in Figure 2 fifteen times. Each time they had to choose that movie, in which Robovie-R2 (or in a different survey Robovie-II) seemed to behave most natural to them.

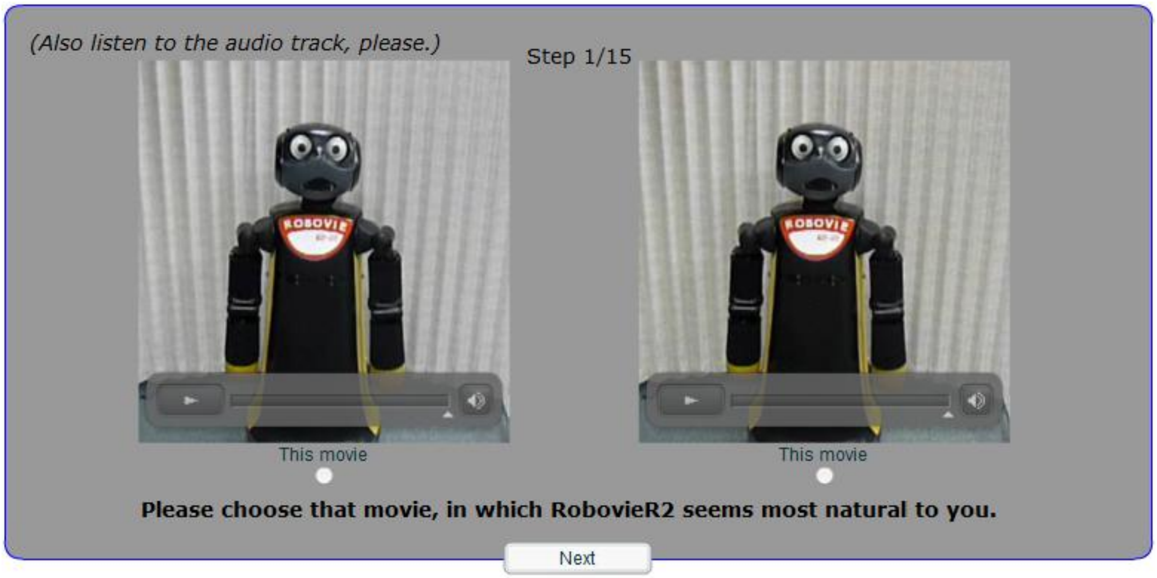

Figure 2: A screen-shot of the online interface: The presented movies were always different to each other and participants were forced to choose one of them, before they could proceed to the next pairing by pressing "Next".

This way we realized a pair wise sequential presentation of a total of six movie clips per robot. Each of these six video clips featured the same last sentence of the joke, the same movements of the robots, and the same Japanese exclamation "Ariehen!" (meaning "unbelievable") in the end. The only difference between movies was the type of auditory laughter produced in response to the joke. Five laughter sounds were manually chosen out of a total of 402 Japanese laughter instances that had been extracted from dyadic smalltalk recordings (Ishi, Ishiguro, & Hagita, 2008). The restriction to female laughter for both robots was motivated, first, by the robot's speech synthesis being based on a female voice as well and, second, by our belief that there were still enough variations possible to realize laughter. To produce an artificial, more child-like laughter, we pitched one sample up by 25% (keeping its duration constan), because we wanted to see how childlike laughter would be judged for our humanoid robots. The characteristics of these six types of laughter are summarized in Table 1.

Table 1: Pitch, number of pulses, duration, and gender of each laughter

	Pitch	Number of pulses/duration	Gender
Laughter 1	Very high (constant pitch contour)	6 / 1.25 seconds	Ambiguous (artifical)
Laughter 2	Mid-height (same as above)	6 / 1.25 seconds	Female
Laughter 3	High decreasing to mid-height	7 / 1.47 seconds	Female
Laughter 4	Rather low ("smoky" voice quality)	8 / 1.48 seconds	Female
Laughter 5	Mid-height	8 / 1.74 seconds	Female
Laughter 6	High	3 / 0.9 seconds	Female

While the robots were laughing they moved their heads backward to the left and lifted their arms resembling an "open-hand" gesture (cp. Figure 1).

The two robots were presented in two independent online surveys, which are subsequently labeled "survey A" for Robovie-II and "survey B" for Robovie-R2. Table 2 shows the distribution of gender among surveys, the total amount of participants per survey, and the distribution of the participants' origins.

Table 2: Distribution of gender and participants' origin per survey

	Male	Female	Asian	European	American	Σ
Survey A	30	20	12	21	17	50
Survey B	25	8	12	17	5	34
Σ	55	28	24	38	22	84

The mean age of all 50 participants of survey A is 30.4 years (standard deviation (STD) 7.365) and the 34 participants of survey B were in average 29.3 years old (STD 5.75). Thus, this insignificant difference is neglected.

4.2 RESULTS

The different outer appearances of the two robots seem to have no effect (cp. Figure 3). Only laughter number five, which contains a lot of breathing, was judged significantly less natural (p = 0.02) for Robovie R2 (mean 1.12, STD 1.2) than for Robovie II (mean 1.82, STD 1.64). Neither any other statistically significant differences between robots nor any global gender effects appeared. Although a difference between robots seems to exists with regard to the naturalness of the child-like laughter number one (survey A: mean 1.78, STD 1.45; survey B: mean 2.47, STD 1.55, cp. Figure 3), this result is not statistically significant (p = 0.054)[1].

Figure 3: Mean values and standard deviations of the results for Robovie-II and Robovie-R2

In the aim to find an answer to question 3b, we took a global look at intercultural differences by pooling the data of both surveys, cp. Figure 4. Participants originating from the American continent (n=22, mean 1.45, STD 1.41) judged the child-like laughter number one as significantly less natural than did the Asian participants (n=24, mean 2.42, STD 1.47, p = 0.03). The average opinion of the thirty-eight European participants, however, was not significantly different from either one of the two other cultural groups (mean 2.04, STD 1.52) in case of this child-like laughter. Furthermore, participants of each of the three groups evaluated laughter number two as most natural.

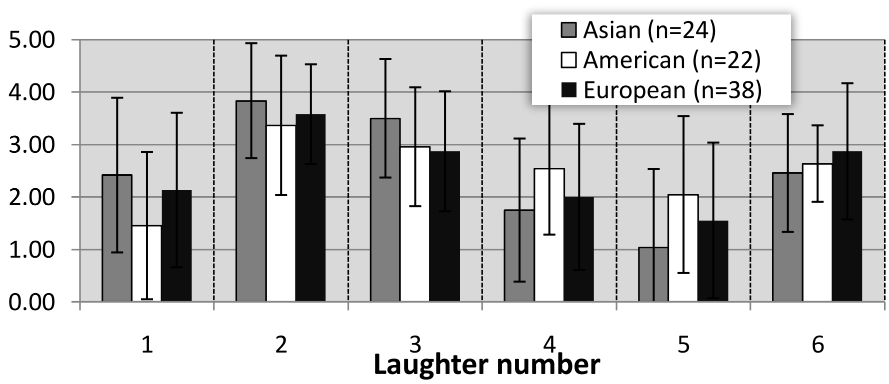

Figure 4: Mean ratings with standard deviations divided according to participants' cultural background distinguishing Asian, American, and European origin

4.3 DISCUSSION

In summary, a robot's outer appearance seems to have a much smaller effect on the perceived naturalness of laughter than we expected. Probably any real differences are dominated by the judged naturalness of the different types of

[1] All reported p-values are based on two tailed t-tests assuming unequal variances and we assume 0.05 as our level for statistical significance.

laughter themselves, but some participants also reported that they thought any kind of male laughter would fit better to our humanoid robots than any of the female laughter that we presented.

In line with this criticism we found that Japanese high school students reported in another study that they would have preferred male laughter for Robovie-II as well (Becker-Asano, Kanda, Ishi, & Ishiguro, 2009). Accordingly, it is planned to acquire additional data on the naturalness of different types of male laughter in the future.

5 EMOTIONAL EFFECTS OF GEMINOID'S LAUGHTER IN THE ULTIMATUM GAME

"Geminoids" are very anthropomorphic robots with such a realistic outer appearance that they can easily be mistaken for being human. The word "geminoid" is a combination of the Latin word *geminus*, meaning "twin" or "double", and the postfix *–oides*, which translates to *similarity*. The first prototype "Geminoid HI-1", thus, works as a very realistic, robotic copy of a real person and can be tele-operated from a remote location.

With Geminoid HI-1 we follow two research directions: First, we incessantly revise the tele-operation devices for an operator to feel present at Geminoid's location. Second, we evaluate Geminoid's performance in direct social interaction using it as a tool for interdisciplinary research to gain insights that are transferable to human-human interaction.

Following this second motivation Geminoid HI-1 was programmed to participate in a playful interaction taking the role of an experimenter in a game that was played by two humans. In doing so we aimed to investigate question 1b addressing the technical realization of laughter synthesis in combination with robotic appearance as well as questions 2a and 2b, because we designed for a specific situational context and combined Geminoid's auditory laughter with whole body movements including directed eye gaze.

We decided to let two humans play a variant of the "Ultimatum Game" (Güth, Schmittberger, & Schwarze, 1982) to establish a specific situational context, in which Geminoid HI-1 would start laughing in certain moments of the game. This way we could not only make sure that participants ascribe a certain role to Geminoid, but we also had better control over the dynamics of the interaction.

5.1 OVERVIEW OF THE ULTIMATUM GAME

In our version of the Ultimatum Game two players (the participant P and his or her human opponent O, cp. Figure 5) take turns in proposing to one another how to split a total of 100 Yen between them. Although these decisions could be announced directly to the other player, we told our participants to point to one of three cards in front of them instead. Because an optical barrier is placed between the two players, this pointing cannot be observed directly by the other player. Geminoid (G in Figure 7), however, being placed at the table's head side sees the player's indication and announces the offer to the other player.

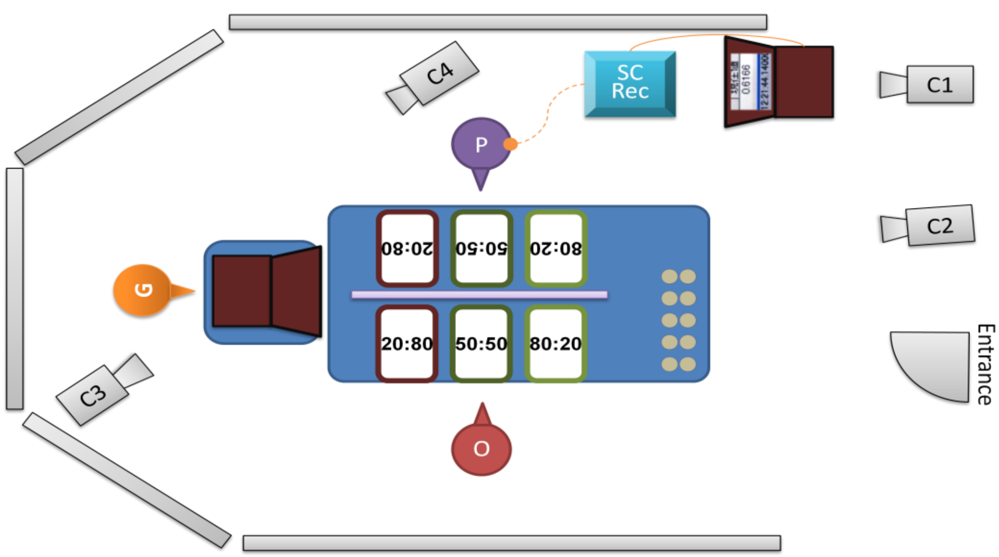

Figure 5: The setup of the "Ultimatum Game" with the participant (P) entering the room from the right, Geminoid HI-1 (G) sitting behind a computer to the left, and the opponent (O, our confederate) opposing the participant. The cameras C1 to C4 and the skin conductance measurement (SC Rec) were set up as indicated.

Only if the other player accepts the offer, the money will be split accordingly. The players can only choose to split the money as presented in Table 3. If, however, the opposing player declines the offer, all money is put aside and both players remain empty-handed in this round of the game. Then it is the other player's turn to decide how to split another pile of ten Yen coins worth a hundred Yen following the same procedure.

Table 3: The three different choices the players can take to propose how to split the money. "Fairness" is rated from the point of view of the participant being offered the respective amount of money.

Card label	Description	Fairness
"20:80"	The opponent keeps 20 Yen for him- or herself and gives 80 Yen to you.	Altruistic
"50:50"	The opponent keeps 50 Yen for him- or herself and you get 50 Yen as well.	Fair
"80:20"	The opponent keeps 80 Yen for him- or herself and you receive the remaining 20 Yen.	Unfair

Theoretically, assuming purely rational agents, who aim to maximize their own profit, a recipient should accept every offer, even if it seems to be "unfair". In reality, however, humans tend to decline unfair offers as was found in several studies of economics (e.g. (Güth, Schmittberger, & Schwarze, 1982)). They seem to be influenced by their emotions, which in this case might result from moral judgments of social adequateness of behavior.

The presence of a third person in the role of a neutral experimenter should not change the player's decisions, but what if this person suddenly starts laughing at the recipient? How does the participant's opinion about this third person change? How does he or she feel towards this person?

These are the questions we aimed to address with our study detailed next.

5.2 THE EMPIRICAL STUDY

For studying the effects of laughter in this explicit situational context we decided to follow a within subject design such that each of the participants played both of the following two conditions once[2]:

1. Control condition: The participant and the opponent (who was always the same informed student of our lab) took turns in deciding, how to split a total of 100 Yen each turn. After exactly ten turns the game ended and the amount of money each player won was noted on paper, if this was the first condition to be followed by the laughter condition.
2. Laughter condition: Geminoid mostly performs in the same way as in the control condition. However, in addition it starts laughing at the participant, whenever the participant's opponent makes an unfair offer and just before announcing this offer to the participant.

Figure 6: The opponent makes an unfair offer (left) and Geminoid turns to the participant and—only in the laughter condition—laughs at her (right) just before announcing the opponent's decision.

Geminoid's laughter with its accompanying body movement during the laughter condition is illustrated in Figure 6. The left picture shows that moment in time, in which our confederate, i.e. the participant's opponent, makes an

[2] The order of conditions was counterbalanced between participants to avoid order effects.

unfair offer. He was instructed to do so exactly three times in every game regardless of the experimental condition. In the remaining two times of each game he always had to make one altruistic offer and one fair offer (cp. Table 3).

Accordingly, Geminoid was laughing three times in the laughter condition. Similar situations happened three times in the control condition as well, but then Geminoid directly informed the participant about the offer without laughing or showing any other emotional reaction. Thus, we can now perform a within-subject analysis for differences in the conscious and unconscious reactions of each participant depending on the presence or absence of laughter. The relative change of each participant's skin conductance level (SCL) and the participant's reported feelings toward Geminoid, which were acquired by questionnaires, are the dependent variables.

5.2.1 Procedure

A total of thirty-six Japanese university students were paid to come to ATR individually for a total of 3 hours to participate in a couple of experiments the first of them being the one reported here. Twenty-six of them were male with an average age of 22.5 years (standard deviation (STD) 1.45 years) and 10 were female with an average age of 21.6 years (STD 2.17 years).

First a student of our lab explained to each participant after arrival at ATR outside of the experiment room how to use a Japanese version of the "Geneva Emotion Wheel" (GEW; see (Scherer K. R., 2005); downloaded from http://www.unige.ch/fapse/emotion/ on 12/3/2008; see also Section 5.2.2) and that they would play a simple game later on, in which they could win a small amount of money. All instructions were provided on paper in Japanese and we asked each participant about his or her name, age, gender, nationality, and major of studies before the experiment began. We also asked them to sign a consent form in advance.

Next, our confederate student of the lab let the participant into the experiment room and the first author, who is easily being recognized as a non-Japanese national, always entered the room directly behind each participant. Thus, in nearly all cases the participants turned around and were surprised about the presence of a non-Japanese. After our Japanese student introduced the first author by his name, the first author (in broken Japanese) greeted the participant, mentioned that he is German, and invited the participant to take a seat at the right side of the table (cp. Figure 5).

Probably due to this distraction several participants asked the student after taking their seat, why they had not been introduced to the older Japanese person next to them. Our student then explained that Geminoid HI-1, i.e. the "person" their question referred to, is only a robot, which might not need to be introduced in the same way as a cooperate researcher from Germany. After that the Japanese student gave the participant written instructions about the rules of the Ultimatum Game and answered questions until the participant fully understood the procedure of the game. On page two of these instructions we additionally asked the participants, if they had either never seen Geminoid HI-1 before (n = 25), or knew the android from the media (n = 6), or even had prior face-to-face experience with Geminoid already (n = 5).

During this time the first author prepared the "Coulbourn Instruments LabLinc" biometry measurement device, which was used in combination with a digitizer to digitally record each participant's level of skin conductivity on a computer for later analysis[3]. After the participants had confirmed that they understood the procedure and the rules of the game, the first author attached the device's electrodes to the non-dominant hand's palm of the participant (cp. Figure 6) and started the measurement.

The participant was then asked by the Japanese student to fill in a blank version of the GEW to describe how he or she felt directly after entering the experiment room. This way we acquired baseline data for the following two times, in which we applied the Emotion Wheel again, and it gave our participants a chance to get used to this means of reporting on their emotions. After this step, the first author set the skin conductance measurement to zero, before the participant was confronted with a series of pictures on a laptop screen, of which two showed arousing scenes. This was followed by three minutes of relaxation, before the skin conductance measuring device was recalibrated to zero and the first author left the experiment room to control Geminoid HI-1 remotely (cp. Figure 7).

[3] This analysis is ongoing work and, thus, we cannot report on results here and don't provide a detailed description of the setup.

Figure 7: The combined view of all four cameras (left), which is used at the tele-operation console (right) to control Geminoid HI-1 remotely by means of buttons, which trigger predefined movements with utterances in Geminoid.

After another minute of relaxation our student placed the barrier between himself and the participant (see Figure 7, left) and the game started with Geminoid looking up and greeting both players by either saying "Good morning!" ("Ohaiou gouzaimasu!") or "Good day!" ("Konnichi wa!") depending on the time of day. Then it turned to the participant and asked "Is everything fine?" ("Jumbi wa ii desuka?") and waited for his or her response, which always was "Yes!" ("Hai!") although some participant seemed to be a little confused and didn't respond immediately. Finally, the game started with Geminoid turning to the participant's opponent while saying "Ok, let's start!" ("Dewa, ganbatte kudasai!").

During the game Geminoid alternately first waited for one player's decision, then nodded at that player, and finally announced the decision to the other player. In the laughter condition, as described above, this sequence was interrupted by Geminoid's laughter after our student had made an unfair offer and Geminoid had nodded. While Geminoid waited for the decision of the recipient, it looked at him or her and repeatedly nodded slightly as if to encourage him or her to accept or decline the offer. Although the recipient announced his decision acoustically and therefore clearly perceivable for the other player, we let Geminoid say "One moment, please." ("Chotto matte kudasai.") while it pretended to type on the keyboard in front of it. As Geminoid also shifted its gaze from looking at the recipient down to the keyboard (see Figure 7, left), it appeared natural to let it finally look back to the same player saying "Please." ("Douzo."), as if to encourage that player to begin the next turn.

The game ended after our student decided about the participant's fifth and last offer. At that moment Geminoid looked left and right while saying "The game is finished. Thank you very much." and finally looked down at the computer in front of it, which was also the initial posture in the beginning of the experiment.

In the following our student asked the participant to describe his or her feelings toward Geminoid by means of a second GEW. Participants also could write down a reason for their feelings, if they liked. Additionally, they were asked how much they thought Geminoid had either favored them or our student during the game and how fair or unfair our student had played in their opinion. The same questions were asked after the second game, which began next with Geminoid saying once more "Is everything fine?" ("Jumbi wa ii desuka?").

As we were afraid that an order effect might occur, we counterbalanced the order of conditions. Accordingly, 18 participants (13 male and 5 female) played the control condition first, followed by the laughter condition, and another 18 participants (13 male and 5 female) played the conditions in reverse order starting with the laughter condition.

5.2.2 The Geneva Emotion Wheel

As described in the previous section, each participant was asked three times to report on his or her subjective emotions using the Geneva Emotion Wheel (Scherer K. R., 2005). This wheel is a circular arrangement of 20 emotion families, which themselves are represented by two prototypical emotion terms.

We developed a Japanese version of this measurement tool by means of formal back-translation and subsequent discussion. In order to avoid misinterpretations of the Kanji characters, we decided to include small, so-called Furigana on top of each Kanji. In addition, we translated the instructions for the Emotion Wheel to Japanese (also by means of formal back-translation) and added all necessary information about our special situational context.

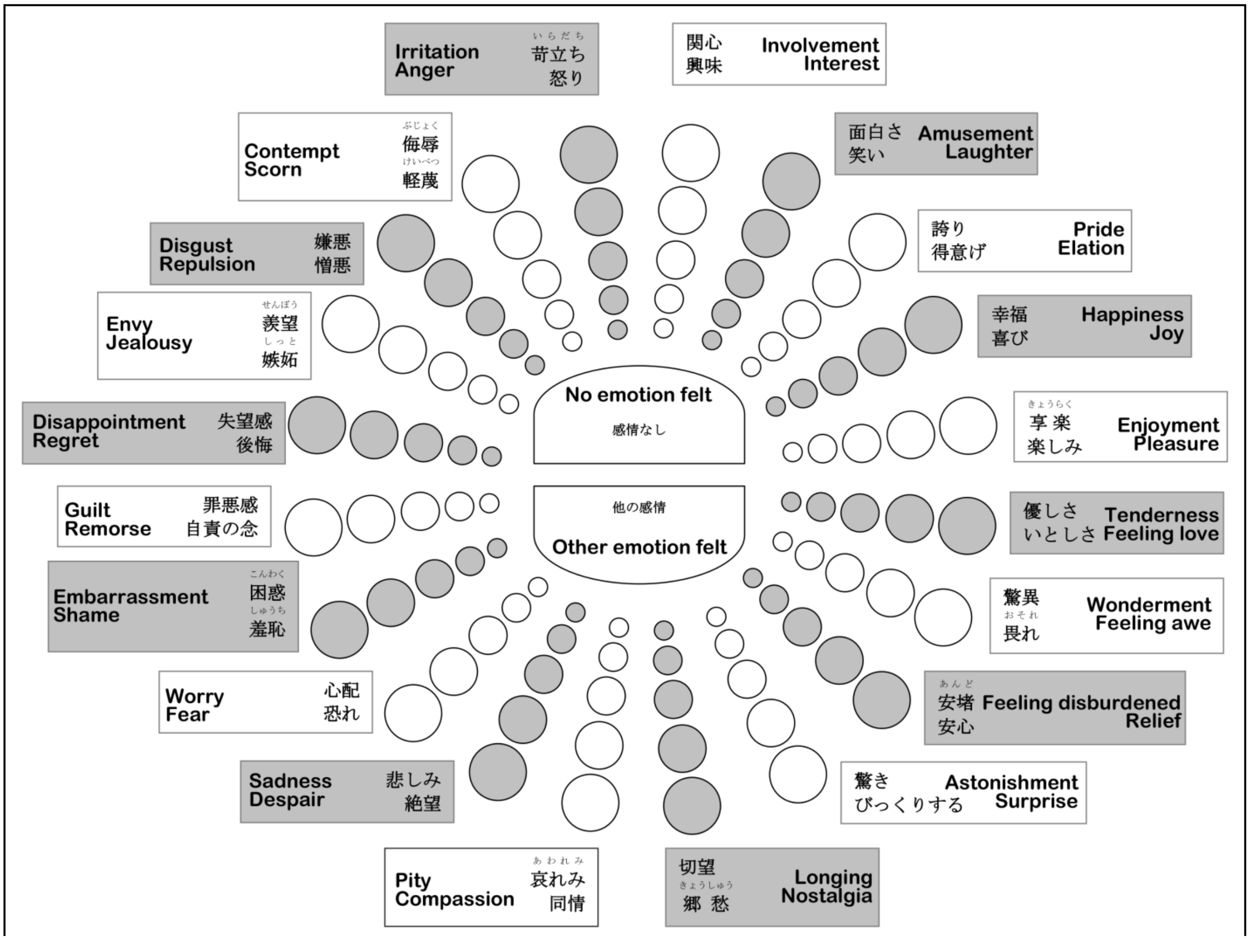

Figure 8: The Geneva Emotion Wheel with its translation to Japanese. (The English emotion terms were not presented to the participants.)

After each game the participants were provided with a blank GEW and they were instructed to indicate their feelings toward Geminoid in the following way:

"You might decide for none, one, or two emotion families first and then indicate each emotion family's intensity independently by choosing a smaller circle for lower intensity or a bigger circle for higher intensity of that emotion family. If you did not feel any emotion during the [first/second] session, please make a cross in the center of the wheel at 'no emotion felt'. If you felt an emotion during the [first/second] session, which is not described by the emotion families presented in the GEW, please write its name in the center of the wheel below 'other emotion felt'."

The general instructions, which were handed out and explained to the participants before they entered the experiment room, stated even more clearly that the emotion terms are to be interpreted as representatives of a whole set of emotion families. Thus, even if a participant has an emotion term in mind, which describes his feelings but is not present in the emotion wheel, he or she might decide to choose that emotion family, which is closest to the imagined emotion term. For the analysis we encoded the emotion families' intensities either with zero for not checked or with one up to five for each level of intensity.

5.2.3 Results

In the following we will report on first results of our analysis, which is motivated by the following two hypotheses:

1. The presence or absence of laughter should not influence judged fairness of our student, who in both conditions followed the same fixed strategy in making his offers and accepting or declining the participant's offers.
2. Geminoid's laughter is most likely interpreted as "laughing at" the participant and, thus, we expect the participant to appraise Geminoid negatively and as joining our student's side in the game, when

Geminoid is laughing. In the control condition, however, Geminoid should be appraised more positively in general and neutral with respect to the game itself.

To address the validity of the first hypothesis, we will first present an analysis of the outcome of the game itself as well as the answers to the question concerning the fairness of our student. To validate the second hypothesis, we will then analyze, first, the answers to the question about whose side Geminoid favored during the game and, second, results from our analysis of the participants' responses on the GEWs.

When laughter has no effect

Following a specific line of thought it is reasonable to assume that Geminoid's laughter might have a direct effect on the participant's willingness to accept unfair offers of our student:

"Geminoid is laughing at me, whenever the student makes an unfair offer. Thus, Geminoid makes fun of me and allies with the student of the lab. This is making the situation even more unfair than the offer itself already is and therefore I will not accept the offer."

If most of our participants had followed this line of thought, we should get a higher number of refusals of unfair offers in the laughter condition than in the control condition. The average amount of money won in the laughter condition should also be significantly less than the average amount won in the control condition. The analysis of our data, however, provides a different picture.

Participants' acceptance rate was nearly the same for the control (mean = 1.89 times out of three) compared to the laughter (mean = 1.83 times) condition. Furthermore, participants won an average of 380.00 Yen (STD 75.52) in the control condition and only slightly less, i.e. in average 369.72 Yen (STD 97.88), in the laughter condition. Therefore, we cannot say that Geminoid's laughter directly influenced a participant's decision during the game.

Next, we consider a possible difference between conditions in the judged fairness of our student. The participants were asked before the first session and after each of the two following sessions, how they thought about the student's fairness in general (i.e. just before starting with the game) and after each game. Each time they indicated their judgments on a scale from minus three, labeled "very unfair", to plus three, labeled "very fair". To analyze for differences between conditions, we first subtracted the initial pre-game fairness judgment from the following two judgments for each participant separately. Then we calculated the respective means and standard deviations for each condition resulting in an average fairness judgment of 0.64 (STD 1.59) for the control condition and 0.33 (STD 1.51) in case of the laughter condition. The difference between these two mean values is not significant ($p = 0.41$) and we come to the conclusion that laughter had no effect on the judged fairness of our student in the game as well.

These results are in line with our first hypothesis that laughter should not affect the game nor the appraisal of the student himself directly.

When laughter makes a difference

So far, one could think that the effect of an android's laughter is much weaker than expected. We will now, however, report on results of our analysis showing that laughter indeed has an effect, at least when being produced by an android in combination with its gaze being directed at the participant.

The most direct way to address hypothesis two was by asking the participant, which person Geminoid might have favored during the game, the student or him- / herself. The answers to this question have been encoded with minus three to indicate that Geminoid strongly favored the participant up until plus three for Geminoid strongly favoring the student. In result, the participants reported after the control condition that Geminoid would have been rather neutral (mean 0.03, STD 0.17). In contrast, they reported after the laughter condition that Geminoid would be favoring the student (mean 0.72, STD 1.19). The difference of 0.69 between conditions is statistically significant ($p < 0.01$) and means that in the eyes of our participants Geminoid seemed to ally with the student of our lab when laughing at the participant.

The results so far could also mean that participants perceived Geminoid's laughter as negative and irritating. To substantiate this assumption we will now present an analysis of the GEW data (cp. Figure 9). First, we calculated the mean intensities of all 20 emotion families separately for each condition. These values are presented in the 40 boxes below the emotion families in Figure 9. As stated in Section 5.2.1, the highest possible intensity was encoded as 5 and the lowest possible intensity as 1. Participants could only mark the independent intensities of up to two emotion families, so that at least 18 emotion families were always encoded with zero intensity. This explains why most average intensities remain below 1.0 for both conditions.

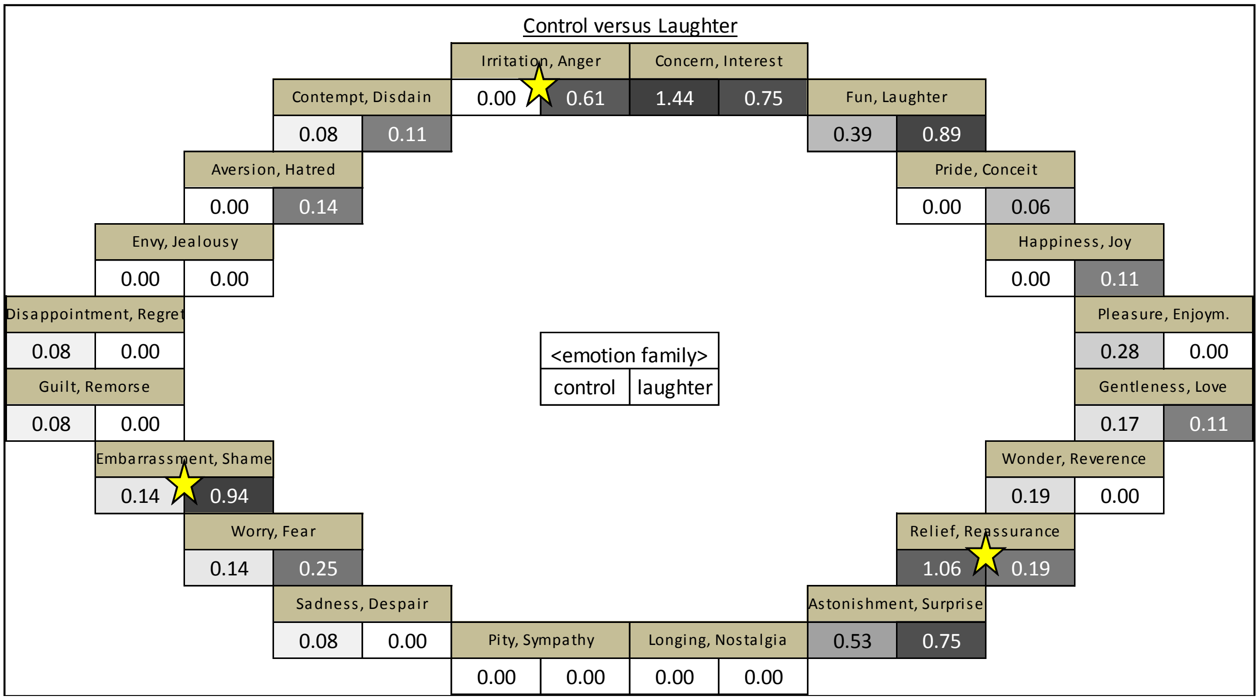

Figure 9: Mean values of the reported emotions felt by the participants toward Geminoid separated between control condition (all boxes to the left below each emotion family) and laughter condition (boxes to the right). Significant differences between condition are indicated with a star.

Most often our participants reported to feel “concern” and “interest” toward Geminoid (mean 1.44 in the control condition and mean 0.75 in the laughter condition, difference not significant). This emotion family is followed by “astonishment / surprise” with a combined average intensity of 0.64, which is not only by its intensity but also by its position in the emotion wheel close to the emotion family “relief / reassurance”. In case of the latter, however, we find a significant difference between conditions with respect to the reported emotion intensities ($p < 0.01$). “Relief / reassureance” is more often felt toward Geminoid after the control condition than after the laughter condition. After further separating the data into those control conditions, which have been played before the laughter session and those after the laughter session, we get a lower average intensity of “relief / reassurance”, when the control condition is played first (mean intensity of 0.83, if the control condition is the first session, and mean intensity 1.28, if it is the second session). Accordingly, we believe that our participants felt relieved when Geminoid did not laugh any more in a control condition that followed a laughter session.

In contrast to the result on “relief / reassurance” we found a significant difference in the opposite direction for “embarrasement / shame” (control condition mean 0.14 and laughter condition mean 0.94; $p < 0.014$). Our participants felt much more ashamed after the laughter condition than after the control condition—an assumption that finds support when taking the order of conditions into account again, because only after the first sessions, regardless of the experimental condition, “embarrasement / shame” is being reported. Probably the participants got used to the situation, when playing the second session. Their feeling of shame might also have resulted from the unusual experimental setup itself rather than being caused by Geminoid’s laughter alone.

Finally, we also found one more significant difference, which directly supports our assumption that our participants found Geminoid’s laughter negative and irritating. In fact, some participants obviously got angry during the course of the experiment, as could be derived from their behaviors and facial expressions. Therefore, it is not surprising that participants chose “irritation / anger” quite often to describe their feelings toward Geminoid. Interestingly, this only happened after the laughter condition had been played (mean intensity 0.61) and this intensity was significantly different from the control condition ($p < 0.01$). In case of this emotion family the order of conditions had no effect (first session’s mean for laughter condition 0.67 and second session’s mean 0.56). Thus, we take this as argument for assuming that “irritation / anger” directly correlates with the presence or absence of Geminoid’s “laughing at the participant”.

6 CONCLUSIONS

Taking a look at all results together, we come to the preliminary conclusion that the social effect of laughter heavily depends on at least the following three factors:

1. The situational context, which is not only determined by the task at hand, but also by linguistic content as well as non-verbal expressions. From the results of the online survey we learned that explicitly stating a situational context (e.g. “laughing in response to a joke”) helped to narrow down the number of factors, which our participants had to take into account to evaluate the robots’ laughter. The careful design of Geminoid’s “gazing at the participant” behavior also seemed to have the expected effect of its laughter being perceived as “laughing at someone” rather than “laughing with someone”.
2. The type and quality of laughter synthesis in combination with an artificial laugher’s outer appearance. The comments we got in the Robovie survey suggest that we might have to take different expectations concerning a robot’s gender into account. Geminoid HI-1, however, is obviously male, but the reported irritation might have resulted from a mismatch between the recorded laughter and the recorded voice, which we simply played one after the other. We are now discussing ways to smooth the transitions between laughter and spoken language / synthesized voice to improve the overall naturalness.
3. The interaction dynamics, which is partly also depending on a perceiver’s gender, personality, and cultural as well as educational background. We found a small effect resulting from the difference in cultural backgrounds of our participants in the online survey that encourages us to further investigate this aspect. Based on these experiences we limited the participants’ educational background for the Geminoid study such that only university students of nearly the same age were invited to participate. Another factor in this context might be the gender and appearance of Geminoid HI-1. It is only possible to generalize the results to a limited extent, because Geminoid itself is an outstanding and therefore unusual robot. As it is modeled to closely resemble a real human, who is the last author of this paper, we might compare Geminoid’s social effects with those of its real human counterpart by replicating the experiment with him.

In summary, we are confident that social robots and androids should make use of laughter to perform more humanlike and sociable in a future society that they will have to share with us. While carefully engineering robots with the ability to produce laughter, we might also gain a deeper understanding of the fundamental processes, which let us humans enjoy to laugh with and at others.

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REFERENCES

Bartneck, C. (2002). *eMuu - An Embodied Emotional Character for the Ambient Intelligent Home.* Universiteit Eindhoven.

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, Decision Making and the Orbitofrontal Cortex. *Cerebral Cortex , 10*, 295-307.

Becker, C., Kopp, S., & Wachsmuth, I. (2007). Why emotions should be integrated into conversational agents. In T. Nishida (Ed.), *Conversational Informatics: An Engineering Approach* (pp. 49-68). Wiley.

Becker, C., Prendinger, H., Ishizuka, M., & Wachsmuth, I. (2005). Evaluating Affective Feedback of the 3D Agent Max in a Competitive Cards Game. *Affective Computing and Intelligent Interaction* (pp. 466-473). Beijing, China: Springer.

Becker-Asano. (2008). *WASABI: Affect Simulation for Agents with Believable Interactivity.* Amsterdam: IOS Press.

Becker-Asano, C., Kanda, T., Ishi, C., & Ishiguro, H. (2009). How about laughter? Perceived naturalness of two laughing humanoid robots. *Affective Computing and Intelligent Interaction.* Amsterdam: IEEE.

Breazeal, C. (2003). Emotion and sociable humanoid robots. *International Journal of Human-Computer Studies , 59*, 119-155.

Cowley, S. J. (2008). Social Robotics and the person problem. *Proceedings of AISB 2008 Convention.* Aberdeen: The Society for the Study of Artificial Intelligence and Simulation of Behaviour.

Dautenhahn, K., Nourbakhsh, I., & Fong, T. (2003). A Survey of Socially Interactive Robots. *Robotics and Autonomous Systems , 42*, 143-166.

Elliott, C. (1992). *The Affective Reasoner. A process model of emotions in a multi-agent system.* Northwestern University. Institute for the Learning Sciences.

Gervais, M., & Wilson, D. S. (2005). The Evolution and Functions of Laughter and Humor: A synthetic approach. *The Quaterly Review of Biology , 80*, 395-430.

Grammer, K. (1990). Strangers meet: Laughter and nonverbal signs of interest in opposite-sex encounters. *Journal of Nonverbal Behavior , 14*, 209-236.

Grammer, K., & Eibl-Eibesfeldt, I. (1990). The ritualisation of laughter. In *Natürlichkeit der Sprache und der Kultur* (pp. 192-214). Brockmeyer.

Güth, W., Schmittberger, R., & Schwarze, B. (1982). An experimental analysis of ultimatum bargaining. *Journal of Economic Behavior and Organization , 3*, 367-388.

Hayashi, K., Kanda, T., Miyashita, T., Ishiguro, H., & Hagita, N. (2008). Robot Manzai: Robot conversation as a passive-social medium. *International Journal of Humanoid Robotics , 5*, 67-86.

Hollnagel, E. (2003). Is affective computing an oxymoron? *International Journal of Human-Computer Studies , 59*, 65-70.

Ishi, C., Ishiguro, H., & Hagita, N. (2008). Analysis of inter- and intra-speaker variability of head motions during spoken dialogue. *Proceedings of the International Conference on Auditory-Visual Speech Processing*, (pp. 37-42).

Kanda, T., Ishiguro, H., Ono, T., Imai, M., & Mase, K. (2002). Multi-robot cooperation for human-robot communication. *International Workshop on Robot and Human Interactive Communication*, (pp. 271-276).

Kipper, S., & Todt, D. (2001). Variation of sound parameters affects the evaluation of human laughter. *Behavior , 138*, 1161-1178.

Laskowski, K., & Burger, S. (2007). On the Correlation between Perceptual and Contextual Aspects of Laughter in Meetings. *Proceedings of the Interdisciplinary Workshop The Phonetics of Laughter*, (pp. 55-60). Sarrbrücken.

LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience , 23*, 155-184.

Panksepp, J. (2000). The Riddle of Laughter: Neural and Psychoevelutionary Underpinnings of Joy. *American Psychological Society , 9*, 183-186.

Picard, R. (2003). Affective computing: challenges. *Int. J. Human-Computer Studies , 59*, 55-64.

Picard, R. W. (1997). *Affective Computing.* The MIT Press.

Prendinger, H., Becker, C., & Ishizuka, M. (2006). A study in users' physiological response to an empathic interface agent. *International Journal of Humanoid Robotics , 3*, 371-391.

Provine, R. R. (2005). Laughing, Tickling, and the Evolution of Speech and Self. *Current Directions in Psychological Science , 13*, 215-218.

Scherer, K. (1994). Affect Bursts. In *Emotions: Essays on emotion theory* (pp. 161-196). Erlbaum.

Scherer, K. R. (2005). What are emotions? And how can they be measured? *Social Science Information , 44*, 695-792.

Schröder, M. (2003). Experimental study of affect bursts. *Speech Communication , 40*, 99-116.

Shiwa, T., Kanda, T., Imai, M., Ishiguro, H., & Hagita, N. (2008). How Quickly Should Communication Robots Respond? *HRI'08*, (pp. 153-160).

Sloman, A. (1999). Review of: Affective Computing. *AI Magazine* .

Vinayagamoorthy, V., Gillies, M., Steed, A., Tanguy, E., Pan, X., Loscos, C., et al. (2006). *Building Expression into Virtual Characters: State of The Art Report.* EUROGRAPHICS 2006.

Yoshikawa, Y., Shinozawa, K., Ishiguro, H., Hagita, N., & Miyamoto, T. (2006). Responsive robot gaze to interaction partner. *Proceedings of Robotics: Science and Systems II.*

Zajonc, R. (1980). Feeling and Thinking: Preferences Need No Inferences. *American Psychologist , 35*, 151-175.

Zecca, M., Roccella, S., Carrozza, M., Miwa, H., Itoh, K., Cappiello, G., et al. (2004). On the development of the emotion expression humanoid robot WE-4RII with RCH-1. *4th IEEE/RAS International Conference on Humanoid Robots , 1*, 235-252.