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Increasing Helpfulness towards a Robot by Emotional Adaption to the User

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Abstract This article describes an emotional adaption approach to proactively trigger increased helpfulness towards a robot in task-related human-robot interaction (HRI). Based on social-psychological predictions of human behavior, the approach aims at inducing empathy, paired with a feeling of similarity in human users towards the robot. This is achieved by two differently expressed emotional control variables: by an explicit statement of similarity before task-related interaction, and implicitly expressed by adapting the emotional state of the robot to the mood of the human user, such that the current values of the human mood in the dimensions of pleasure, arousal, and dominance (PAD) are matched. The thereby shifted emotional state of the robot serves as a basis for the generation of task-driven emotional facial- and verbal expressions, employed to induce and sustain high empathy towards the robot throughout the interaction. The approach is evaluated in a user study utilizing an expressive robot head. The effectiveness of the approach is confirmed by significant experimental results. An analysis of the individual components of the approach reveals significant effects of explicit emotional adaption on helpfulness, as well as on the HRI-key concepts anthropomorphism and animacy.

Keywords Emotions · Adaption · Prosocial Behavior · Empathy · Helpfulness · Similarity · Anthropomorphism · Animacy

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1 Introduction

In any interaction, emotions are an important issue. In 1995, Picard coined the term "Affective Computing" [44]. It describes a form of computing that "relates to, arises from, or influences emotions". Picard pointed out that this might lead to increased performance and decision making for the computer, stressing the importance of such ideas. Today, a large amount of works incorporate this idea. Two main aspects of affective computing are systems detecting emotions in the human user or conversation partner, and systems showing emotions themselves. The detection of emotions and its use in behavior control is treated in several works, e.g., e-learning systems [1], pedagogical agents [17], driver assistants [2], virtual agents [25], psychological assistance [26], etc. However, the effectiveness of automatic emotion recognition is still very limited and the connection between perceived and real emotions remains an open issue. Also in HRI, emotion recognition, expression, and emotionally enriched communication and closed-loop behavior control have gained strong attention during the last two decades [28, 32, 41, 47, 51].

Models from social psychology [20] describe how humans predict events as well as the behavior of other humans [21] and have certain expectations how a conversation partner will react. Analysis of HRI from a social-psychological perspective does not only reveal important implications for hardware design [62], but can also provide a framework and guidelines for the design of robot communication and behavior [27]. In the research field of "Persuasive Technology" [19], non-robotic technologies, such as internet services or mobile devices, are investigated and developed to change attitudes or behaviors of human users through persuasion and social influence, but not through coercion. One example is an interactive mannequin for shop windows to persuade bypassing customers to extend the perceived time they stay in front of a shop window [48].

Most works on social robots are guided by the premise that robots should adapt to humans in order to facilitate intuitive interaction. Nonetheless, proactivity of robots is equally important in order to realize social interaction or to even enable the robot to accomplish its tasks by proactively triggering human behavior [38, 39].

Possible application scenarios are cases where the robot needs the help of humans to achieve a given objective. In the "Interactive Urban Robot (IURO)" project[1], a social robot is developed, capable of proactively acquiring directional information from humans in order to achieve its objective to navigate to certain goal locations in urban environments, e.g. to perform fetch-and-carry tasks like medicine delivery to its human user. By triggering helpful behavior of humans, IURO is robust against dynamic environmental changes, which can not be pre-programmed.

Thereby, the request of the robot for help as well as the willingness of the human to help, can be regarded as social meta communication that serves as a motivational basis for information transfer, e.g. missing task knowledge, see Fig. 1. Thus, for application scenarios where a robot relies on prosocial behavior of humans, triggering human helpfulness is a social sub-task for the robot, necessary to be achieved in order to fulfill its task.

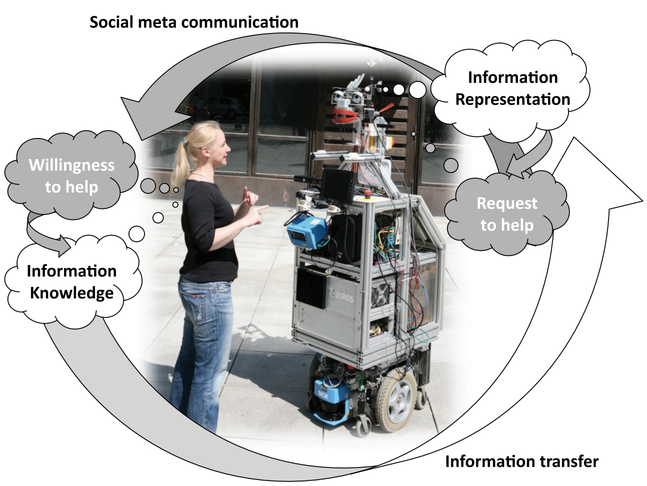

Fig. 1 Social interaction components as a motivational basis for task-related HRI

The willingness of passers-by to support robots asking for directions in public spaces has been investigated in previous outdoor-experiments: According to Weiss et al. [61], "the large number of people interacting arises from the fact that many of the interactions were started by curious passers-by". However, in a long-term perspective, service robots might no longer be a novelty in public spaces and curiosity may pass into rejection.

In this context, this article describes a behavioral approach and integrated system to trigger more prosocial human reactions in terms of increased helpfulness towards a robot. The approach is developed by transferring social-psychological principles from human-human interaction to HRI. The main idea is to trigger helpfulness in a behavioral way, using both, explicit and implicit communication modalities to create empathy and a feeling of similarity.

A number of studies have already been conducted which employ empathy and similarity as factors in human-robot or human-computer interaction to manipulate the user's attitude towards an artificial agent. In relation to this work, they can be categorized whether the artificial agents are used to express empathy [13, 35, 40, 42, 46, 57, 63] or induce it in the user [42, 43, 50] as proposed here.

Empathetic expressions by the agents are mostly utilized to enhance the user experience and thus provide a benefit to the user. Depending on the correct situation awareness and choice of expression, the empathetic reactions can be comforting to the user [46], build trust [13], enhance the system perception by the user [35, 42], enhance the subjective task performance [57] and meet user expectations [40]. The expression of empathy in a particular situation is either based on empirical data [35], a theoretical model [57] or both [42]. Visual [57], auditory [57, 63] or physiological [46] cues or training data from observations of human-human interaction [35] are used to evaluate the situation of the user and express an emotion that is similar to the estimated emotional state of the same.

Another approach is to induce empathy in the user via similarity of the agent. This can, for example, be achieved via facial mimicry [50] or character appearance [43]. While the induction of empathy can enhance the system perception by the user just like the expressive agents, it is also possible to facilitate altruistic behavior of the user. An example is the work by Paiva et al. [43], in which character design provides similarity to the user and thus the educational aspect of bullying prevention should be raised via empathy.

In this work, the approach is to proactively trigger altruistic helpful behavior towards a robot in situations, where helpfulness can be avoided by walking away. Unlike other state-of-the-art approaches, the benefit of empathy and similarity is not user-oriented, i.e. not restricted to the internal states of human users in terms of increased user experience and/or educational success. In contrast, the presented approach is task-oriented with regard to directly trigger external human behavior that benefits the robot to better fulfill its task. This is achieved by transferring theories from Social Psychology [4, 20, 30] to HRI, predicting for situations providing a possibility to avoid helpfulness, that al-

[1] see http://www.iuro-project.eu

truistic helpful behavior cannot be achieved via empathy alone, but only paired with a feeling of similarity in personal attitudes and/or characteristics. Hence, in the proposed approach, similarity is induced by two different ways of emotional expression: by an explicit statement of similarity before task-related interaction, and implicitly expressed by adapting the emotional state of the robot to the mood of the human user, such that the current values of the human mood in the dimensions of pleasure, arousal, and dominance (PAD) are matched. The thereby shifted emotional state of the robot serves as a basis for the generation of task-driven emotional facial- and verbal expressions, employed to induce and sustain high empathy towards the robot throughout the interaction. In the experimental evaluation of the approach, these task-driven emotional expressions are kept as a constant over all experimental conditions to sustain high empathy, while the factors of explicit and implicit emotional adaption are varied in a 2x2 between-subjects design in order to reveal their effects on helpfulness, shown by the user towards the robot in task-related interaction, as well as on user experience.

In a first step, the user-mood is determined by an initial self-assessment by the human participant to be extended by automatic emotion recognition modules in a later stage. The interaction task is exemplarily designed as a person guessing task. The effectiveness of the approach is confirmed by significant experimental results, deduced from 55 test subjects in previous work (see Sec. 2.3), and 84 subjects in the presented study. An analysis of the individual components of the approach reveals significant effects of explicit emotional adaption on helpfulness, as well as on the HRI-key concepts anthropomorphism and animacy.

The remainder of the paper is structured as follows: In Section 2, the background to this work is outlined with respect to social psychological foundations, linguistic definitions on explicit and implicit communication and previous work; Section 3 describes the emotional adaption approach with its explicit and implicit emotional control variables and the methods applied. The technical implementation of the approach in a robotic experimental setting is outlined in Section 4; Section 5 presents the experimental evaluation of the approach, including assumptions & hypotheses, experimental design & measures; results and discussion are described in Section 6; conclusions are given in Section 7.

2 Background

Since the presented approach and its experimental evaluation is motivated by theories from Social Psychology, this section provides an overview on relevant theoretical foundations in human-human interaction and how they are transferred to HRI. Further, explicit and implicit communication modalities are introduced and differentiated by linguistic pragmatics, since they serve as explicit and implicit components of the later presented emotional adaption approach. Previous work is shortly outlined with reference to related results on empathy, serving as a necessary basis for the developed approach to increase helpfulness towards a robot.

2.1 Relevant Theories from Social Psychology

In human-human interaction, "prosocial behavior" in terms of altruistically motivated helpfulness and its determinants is a well-studied field of research [20]. The presented approach is inspired by social-psychological studies [4, 30], where a feeling of being "similar" in terms of having something in common with a person in need of help, e.g. in personal attitudes or characteristics, turned out to be a motivational activator for increased helpfulness towards this person, paired with high empathy. Empathy can be defined as "The capacity to know emotionally what another is experiencing from within the frame of reference of that other person, the capacity to sample the feelings of another or to put one's self in another's shoes" [5]. In other words, the extend of personal distress felt by a potential helper when observing a person in need of help depends on the degree of situationally developed empathy for this person, and similarity is the activating factor for either reacting with altruistically or egoistically motivated behavior:

In situations providing a possibility to avoid helpfulness, e.g. by walking away, referred to as "easy means of escape", the feeling of having something in common with the person in need of help (similarity), paired with correspondingly high empathy, activates altruistically motivated helpfulness. Accordingly, the perceived reward for helping is much higher than the reward for walking away, resulting in high helpfulness, see Tab. 1. In contrast, in the absence of similarity, people would only be highly helpful if there was no or only difficult means of escape. This kind of helpfulness is egoistically motivated to reduce one's own discomfort arising from the empathic reaction on the situation.

Thus, in situations with easy means of escape (as given in most HRI-scenarios), people without a feeling of similarity tend to leave the scene showing low helpfulness towards the person in need of help, since this is an equally efficient way of reducing the negative empathic stimulus. The degree of empathy would not play a role in this case [20]. In Tab. 1, the social-psychological predictions on helpfulness are summarized for situations with easy means of escape, considering the influence of similarity, paired with high empathy.

Since in most HRI-scenarios easy means of escape are provided, the approach is to raise the motivation of human users to help the robot, e.g. in public places. According to the findings of Social Psychology, the approach is to design the interaction in a way to induce similarity between

Table 1 Predictions on helpfulness for situations with easy means of escape according to social-psychological theories [4, 20, 30]

Similarity	Low empathy	**High empathy**
With similarity present	low helpfulness	**high helpfulness**
Absence of similarity	low helpfulness	low helpfulness

the robot and the user, paired with high empathy towards the same.

Hence, in order to increase helpfulness towards a robot, the presented experiments focus on a constant induction of high empathy, paired with the experimentally varied induction of similarity. Constantly high empathy is achieved by emotionally adaptive facial expressions of the robot, as investigated in previous work, see Sec. 2.3, incorporated in the developed approach. Regarding the induction of similarity, an evaluative variation of two different persuasive emotional control variables, developed earlier as components of the emotional adaption approach [22, 23], is applied. The experimentally evaluated parts of social-psychological predictions and corresponding human target behaviors are marked in gray color in Tab. 1.

For the development of persuasive emotional control variables, all available robotic output modalities should be used. The following subsection provides an overview on explicit and implicit communication modalities with regard to their linguistic background and applications in HRI.

2.2 Explicit versus Implicit Communication

In linguistic pragmatics, a distinction is made between explicitly communicated content which is directly said or written, and "implicatures" [8], that enrich and manipulate the pragmatic interpretation of explicitly communicated content. Accordingly, communication modalities are not limited to explicit communication channels like direct verbal or written utterances, but also "silent messages" [36] as implicit communication channels of emotions and attitudes. According to Mehrabian [36] this includes "all facets of nonverbal communication, including body positions and movements, facial expressions, voice quality and intonation during speech, volume and speed of speech, subtle variations in wording of sentences that reveal hidden meanings in what is said, as well as combinations of messages from different sources, e.g., face, tone of voice, words." This holds equally true for HRI, where beliefs about the other's mind are also resulting from interpretation of the other's behavior, that becomes a "sign" of their own minds, by means of implicit and explicit ways of communication [9].

The importance of such "mutual beliefs" in natural language communication is instantiated in the phenomenon of "grounding" [11], meaning that the interpretation of communicated contents has to be at least "approximately correct" in order to achieve successful communication acts, based on a common underlying field of knowledge and/or required actions [59]. Also for artificial social agents, Castelfranchi stresses the importance of a "basic ontology of social action" with special focus on prosocial forms in the mental representations as beliefs and goals of the agent in a social interaction [10].

In the presented approach, focus is set on the adaption of emotional facial and verbal expressions in an implicit and explicit way: An explicit statement of similarity is given by the robot by verbally expressing that it is in the same mood as the user prior to task-related HRI. Implicit emotional adaption is conducted by shifting the base-values of emotion facial end verbal expressions (prosody in speech) towards the user-mood during task-related HRI. The implicit modality of facial expressions has already been explored in terms of inducing high empathy in previous work and is shortly outlined in the following.

2.3 Previous Work

In previous work, the impact of emotional facial expressions on empathy, perceived by human users towards a robot, is explored in a communicative person guessing task [24].

The three tested conditions of facial expressions, shown by the robot, are:
1) *Neutral*: Display of non-emotional facial expressions
2) *Mirror*: Display of the same facial expressions, as shown by the human subjects
3) *Social Motivation Model (SMM)*: Display of facial expressions according to an internal model of social variations of smiling, indirectly mirroring the expressions of the human subjects.

After interacting with the robot, the subjects filled in a set of questionnaires on user experience, and were instructed to rate four statements on situationally induced empathy on a scale from 1 (not true at all) to 5 (completely true). Since this measure was used again in the presented study to be comparable with previous work, the single statements are listed in Section 5.2.5.

Results could be deduced from the experimental evaluation including 55 subjects (40 male and 15 female, between 21 to 60 years with an average age of 28.8). The distribution of the subjects over the experimental conditions was 13 for *Neutral*, 25 for *Mirror*, and 17 for *SMM*. Results showed significantly increased empathy for the *SMM* condition, as can be seen in Tab. 2, as well as other raised dimensions of user experience for emotional animation of facial expressions in an adaptive way to the user, compared with animation in a non-adaptive way during the interaction.

Since the goal of this approach is to achieve the effect of high helpfulness towards the robot under easy means of

Table 2 Situationally induced empathy (on a scale from 1 to 5) and standard deviations (in brackets) [24]

Experiment groups	Empathy
Neutral	3.1 (1.3)
Mirror	3.7 (1.1)
SMM	**4.4** (0.8)

escape (see Tab. 1), it is not sufficient to induce high situational empathy towards the robot. Assuming that principles from social psychology are transferable from human-human interaction to HRI, a feeling of similarity to the robot, in addition to high situational empathy, is expected to lead to higher helpfulness towards the same. Thus, previous work has to be enhanced by an embracing approach, incorporating both, the induction of high empathy and similarity, in order to increase prosocial behavior in terms of helpfulness towards a robot. For this purpose, the emotional adaption approach is developed as described in the following.

3 The Emotional Adaption Approach

The basic idea is to induce both, high empathy and and a feeling of similarity in a human user towards a robot by adapting to the mood of the user and thus providing the human with the impression of sharing the same emotional state as a starting position for the interaction. To achieve this, the emotional adaption approach is divided into two components which express the adaption to the mood of the user in two different ways: explicitly and implicitly. Explicit expression of similarity is given by stating ”me too” when the user was asked about her mood, as outlined more detailed in the Sections 3.1 and 4.1. Implicit expression of similarity is generated using facial and verbal emotion expressions during the HRI task execution that are biased using the mood of the human as measured before the interaction. In the implicit case, as described more detailed in the Sections 3.2 and 4.2, similarity consists of an initial bias of the emotional state of the robot, based on the user mood. In the course of task-related interaction, this bias serves as a shifted baseline for the generation of task-driven emotional expressions of the robot that are included to induce and sustain high empathy in the human user in accordance with the experimental findings of previous work, see Sec. 2.3.

As an example for implicit emotional adaption, previous work showed that empathy and other dimensions of HRI could be improved by the emotional animation of facial expressions to the human user [24]. However, a socially adaptive way of reacting to facial expressions, shown by a user during interaction, requires robust recognition and analysis of the facial action units involved, based on camera images [33]. Since the recognition quality may often be impaired by dynamically changing environmental impacts like varying light conditions or unpredictable background-movements which may distract the focus of a face tracker, the approach of emotional adaption additionally includes an explicit emotional adaption method. Hence, the approach is not restricted to implicitly expressed mimicry or prosodic variations in speech, but also applies explicitly uttered statements to induce similarity, modeled according to underlying social psychological principles. Another advantage is the increased robustness against environmental impacts: If bad performance of automatic speech recognition impairs the explicit part of emotional adaption, the approach may still be robust in terms of implicit emotional adaption. Hence, the goal is to develop two different emotional control variables for prosocial HRI, capable of compensating each other with regard to varying recognition performance of speech or facial expressions, as depicted in the developed behavior model, see Fig. 2: For the robot, the emotional control cycle starts with the input of the user-mood as starting point for emotional adaption mechanisms. This can be achieved by emotion recognition modules or, as applied in the presented study, by an initial self-assessment of the user. Subsequently, the robot initiates the dialog with the user and applies explicit and/or implicit emotional adaption during the interaction. Thereby, the robot persuades the user to show prosocial behavior, e.g. in terms of increased helpfulness towards the robot.

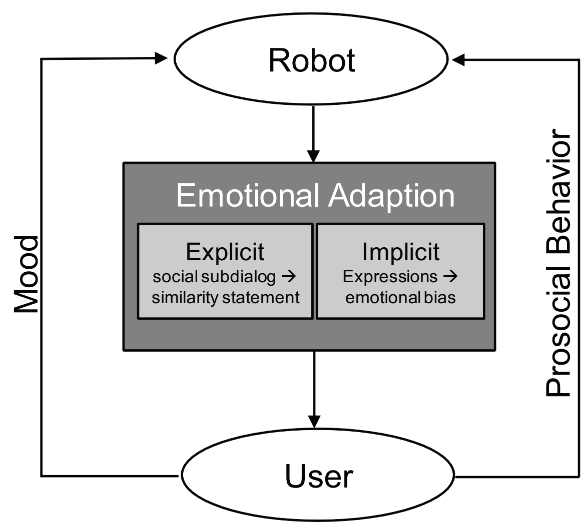

Fig. 2 Emotional control cycle for prosocial behavior in task-related HRI: After the input of the user-mood the robot persuades the user by explicit and/or implicit emotional adaption to trigger more prosocial behavior in turn.

In the following, the two components of the approach, namely explicit and implicit emotional adaption are explained, and related control variables, as used in the presented experiments, are defined.

3.1 Explicit Emotional Adaption

Independent of the interactive goal which is expressed later during task-related human-robot dialog, the idea is to implement some small talk to open the dialog and thereby monitor the current mood or other personal attitudes of the user. Thus, an explicitly expressible basis is provided to induce a feeling of similarity between the user and the robot. Thereby, it has to be considered that this may not match the actual mood but only the mood, the user is willing to communicate because of social conventions and rituals during small talk [58]. However, even when communicating with embodied artificial agents, humans build rapport and trust by means of small talk [6]. The instrumentalized form of small talk used in the presented approach is referred to as “social subdialog” in the following, since triggering helpfulness by means of similarity is regarded to be a social subtask in cases where helpfulness is necessary to fulfill the overall task. In the course of this social subdialog, explicit emotional adaption, and thereby similarity, is created by directly stating a mutuality in an attitude or, as applied in the presented study, in the current mood. Thereby, an impression of having something in common with the user is created.

Accordingly, the emotional control variable of explicit emotional adaption is a directly uttered similarity statement during a social subdialog.

3.2 Implicit Emotional Adaption

Existing HRI-applications using implicit communication channels are based on a communicative mechanism in human-human interaction, called “alignment” [45], that leads to adaptive processes between interlocutors which are essential for human-human interactions [18, 29]. One example is an alignment-approach of emotional facial expressions, where a distinction of automatic, schematic and conceptual levels for emotionally adaptive reactions is made, as partly implemented in the robotic head “Flobi” [14]. In contrast to state-of-the art approaches, this work additionally aims to create a feeling of similarity in users by adapting to their current mood. Thus, an underlying representation of emotiotional states is needed for both, the generation of facial and verbal expressions, as well as for decoding and adapting to the mood of a user: the Pleasure-Arousal-Dominance (PAD) model [37], where emotions are pesented in a continuous three-dimensional space:

- *Pleasure* describes the person’s evaluation of the situation, or, more generally put, how content the person is. High pleasure indicates happiness or gratification, while anger and boredom result in low pleasure values.
- *Arousal* states how agitated the social actor is - regardless of whether this a positive or a negative excitation. High arousal values can be found in angry expressions as well as surprised expressions, while low values can, for example, describe a bored expression.
- *Dominance* is defined as ”a feeling of control and influence over one’s surroundings and others” versus submissiveness, in the sence of ”feeling controlled or influenced by situations and others.” [37]

Advantages of using PAD are for e.g. the supportive evidence for the three dimensional categorization of emotions [37], the ability to express a variety of emotional states in varying intensities (even subtle forms) and the availability of assessment tools like the semantic differential, described in Sec. 4.2.

For implicit emotional adaption, the approach is to use the human-like modalities of facial and verbal expressions in terms of mimicry and prosody in speech, but can be extended to any emotional non-human-like modalities by related PAD-values. Before implicitly adapting to the mood of the user, the emotional state of the user has to be determined and mapped to the continuous PAD space. Ideally, this can be achieved by emotion recognition modules [34, 60], but at least according to an explicit statement in the course of the social subdialog introduced above, and/or in combination with an initial self-assessment of the user on the PAD dimensions. When this is achieved, the robot shifts its base-PAD values for emotional expressions towards the mood of the user as a new starting point for potential emotional variations, e.g. due to task-success or -failure, in the course of the interaction.

Thus, the emotion space, underlying the variations of facial and verbal expressions, is shifted into new boundaries, as depicted in Fig. 3. Accordingly, the emotional control variable for implicit emotional adaption is a “PAD-bias” as

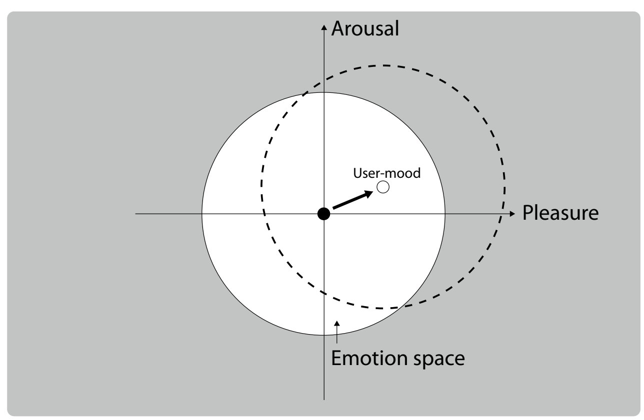

Fig. 3 Implicit emotional adaption: The robot shifts its internal emotional state, underlying the generation of emotional facial and verbal expressions, towards the current mood of the user. The illustration is exemplarily depicted in a 2D-projection on pleasure and arousal, but the experiments also considered the dimension of dominance.

explained more detailed in the following section, where the technical implementation of the approach is outlined.

4 Technical Implementation

The system used in the experiments is the robotic head EDDIE [54], an emotionally expressive robot head, designed as an interaction partner. The head has 23 degrees of freedom, mixing anthropomorphic (human-shaped) and zoomorphic (animal-shaped) features, combining the ears of a dragon lizard, the crown of a cockatoo and human characteristics like eyes, lips and eyebrows. By choosing additional animal characteristics, the robot does not provoke disproportionate expectations concerning the social abilities of the robot [31].

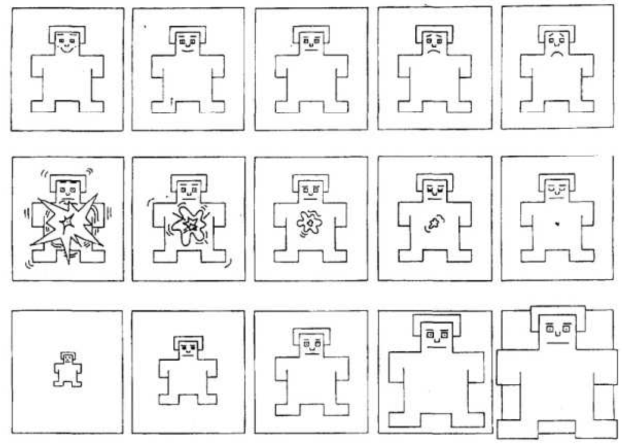

Fig. 4 The SAM scale for measuring PAD values [7]

4.1 Explicit Emotional Adaption: Similarity Statement

For a first evaluation of the explicit emotional control variable in the form of a similarity statement, the social subdialog is conducted by the Wizard-of-Oz (WOz) method: Unknown to the subject, the investigator manually triggers one out of a set of predefined answers to best fit in [49]. In order to create similarity to the test subjects, the robot adapts to the mood of the user explicitly by telling the proband that it feels the same way (good, bad, or mediocre).

In the presented evaluation study, the social subdialog is opened by the utterance “Hello, my name is EDDIE. How are you?”. After the user-input, the robot answers with the adaptive similarity statement “Me too”, followed by “Would you like to play a game?”. If the subject agrees, EDDIE starts the task-related interaction in form of a person-guessing game.

4.2 Implicit Emotional Adaption: PAD-bias

During task-related HRI, the robot implicitly adapts its underlying base-PAD values to the user-mood according to an initial self-assessment, filled in by the users prior to interacting with the robot. Thus, similarity and empathy are created by a shared emotional starting point for the generation of facial and verbal expressions in task-related HRI. As can be seen in Fig. 4, the used Self-Assessment Mannekin (SAM) scale [7] is used in a first evaluative step to replace an emotion recognition module. The scale is a visual way of assessing the three PAD values through images on 5-item semantic-differentials.

Before the game starts, implicit emotional adaption to the user is applied through shifting the base-PAD values of EDDIE by means of an emotional PAD-bias towards the mood of the user in the following way: The original base-PAD values are determined by the internal state of the robot. Before HRI the internal base-PAD values of the robot are neutral. After asking the users about their mood, the change is applied in the following way:

- For users measuring their mood as neutral (3/3/3 for pleasure, arousal and dominance respectively) on the SAM scale, no change takes place.
- For every point the proband moves away from neutral mood on the SAM scale, 25 points are added or subtracted from the base value in the respective PAD-dimension (on a scale from -100 to +100).

Therefore, in case of users feeling very happy (and thus rating their pleasure with a ’1’ on the SAM scale) the robot starts out with a pleasure value of 50 instead of 0, and further changes, e.g. caused by the success in the game described in the following, will influence this value instead of a neutral one.

4.2.1 Generation of Emotional Facial Expressions

The current state in the PAD space is mapped to the joint space of the robot [54]. In this mapping, the pleasure, arousal and dominance values are converted to activations of facial Action Units for emotional expressions. Action Units are defined as muscle groups in the face that lead to observable changes, see the Facial Action Coding System (FACS) for more details [16]. 13 Action Units are emulated by the actuators of the robotic face. Fig. 4.2.1 shows the resulting facial expressions for the PAD values that correspond to the six basic emotions. For example, a surprised robot will raise its brows and unfold its lizard ears.

In the course of task-related interaction, the PAD-variations mainly meet three out of the six basic emotions: happiness, sadness, and surprise, caused by the task-success as reference for the underlying emotional states of the robot. However, the robot needs to be equipped with the full expressive capacity for the six basic emotions, since they may

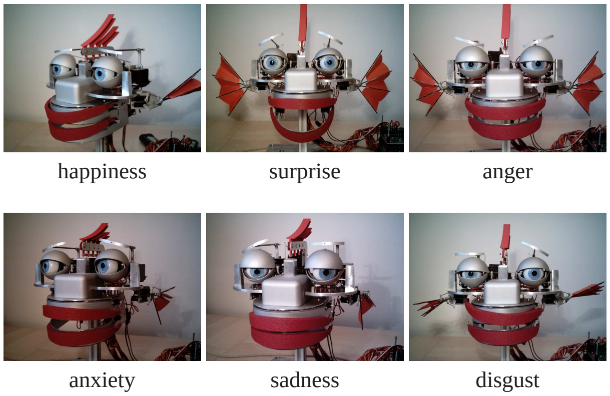

Fig. 5 EDDIE [54] displaying the basic facial expressions, proposed by Ekman et al. [15].

randomly emerge from additional PAD-variations due to the tentative PAD-bias when adapting to the human interaction partner.

4.2.2 Generation of Emotional Verbal Expressions

The MARY Text-to-Speech System [52] from DFKI (Deutsches Forschungszentrum für Künstliche Intelligenz) is used to generate verbal expressions. The XML based interface allows to manipulate the output of the synthesizer on the prosodic level. This method of influencing the prosody based on the emotional state is used to generate emotional verbal expressions and is adapted from Schroeder [53]. The terms evaluation, activation and power used in his work (based on [12]) correspond directly to pleasure, arousal and dominance.

An emotional sentence is first passed from the dialog system, in this case the Akinator game, to a preprocessor module. This module generates the XML structure for MARY based on the current PAD state, altering a set of acoustic parameters to achieve a change in prosody.

The parameter set is selected by Schroeder for being manipulable within MARY. Tab. 3 sums up the maximum values for all acoustic parameters, as well as the influence of the different PAD-values. Each parameter is computed by

$$\beta = 1.0 + f_P \text{ Pleasure} + f_A \text{ Arousal} + f_D \text{ Dominance} \quad (1)$$

$$Acoustic\ parameter = (Basevalue)\ \beta \quad (2)$$

The PAD-values as well as the acoustic parameter-dependent factors f_P, f_A, f_D are in the range of [-1.0,1.0]. The base value is the value for each acoustic parameter that would be used to synthesize the voice in a neutral, non-emotional way. The composition of β in (1) is based on the assumption that a linear correlation between the PAD dimensions and the acoustic parameters exists, neglecting a presumably more complex interrelation, but providing satisfying results in a perception test [53]. The values of the factors f_P, f_A, f_D originate from a combination of corpus analysis, literature review and heuristics [53].

Table 3 Changes to the acoustic base parameters by the emotional speech module, including corrected limit values and changes for better distinction

Acoustic parameter	Variation range	f_P	f_A	f_D
Pitch	-50%, +30%	0.27	0.27	0.09
Range	-80%, +80%	0	1.60	0
Pitch dynamics	-400%, +400%	0	2.00	2.00
Range dynamics	-400%, +400%	0	3.00	1.00
Rate	-70%, +10%	0.20	0.50	0
Accent Prominence	-100%, +100%	0.50	-0.50	0
Accent slope	-150%, +150%	1.00	-0.50	0
Number of pauses	-40%, +40%	0	0.40	0
Duration of pauses	-20%, +20%	0	-0.20	0
Vowel/nasal/ liquid duration	-70%, +70%	0.40	0	0.30
Plosive/fricative duration	-90%, +90%	-0.40	0.50	0
Volume	-66%, +66%	0	0.66	0

The presented values are mainly adapted from Schroeder [53] with some changes: Pre-experiments showed that high changes in pitch, range, rate and number/duration of pauses might lead to the voice sounding unnatural. To present a fitting addition to the facial expressions of EDDIE, these extremes might interfere with the experiment, with users focusing on the few cases when the sound of the robotic voice deviates too much from a human voice. The change of these values, therefore, has been adapted to the experimental environment. Further adaption was possible because the source of the emotion-data mainly focuses on three emotions: a happy/self-assured expression if the task is going well for the robot, a sad expression if the task does not work out the way it should for the robot, and a surprised emotion for sudden gain or loss in confidence during the person-guessing game. As a result, the change in parameters is optimized for these three emotions (high pleasure, medium arousal and high dominance for the first, low pleasure, low arousal and low dominance for the second, and medium pleasure, high arousal and reduced dominance for the third), making the transition from one to the other more easy to recognize. This is especially important due to the continuous input provided by the game, with small alterations in the mood of the robot needing to be perceived distinguishably. The changes concentrate on those acoustic parameters that do not interfere with understandability, namely the duration of the vocals.

In the following, an experimental evaluation of the approach is presented.

5 Experimental Evaluation

In order to evaluate whether or not helpfulness towards a robot can be increased by applying the introduced approach, a setup for a task-related HRI-experiment is designed.

The conducted experiments investigate the persuasiveness of both introduced emotional control variables, namely implicit emotional adaption by means of a PAD-bias, and explicit emotional adaption through a similarity statement in the course of a social subdialog. As a first step, in order to evaluate the presented integrated approach including both components, the combination of implicit and explicit emotional adaption (full emotional adaption condition) has been evaluated in comparison to a non-adaptive condition. As reported earlier, the results showed not only significantly higher helpfulness towards the robot in the full emotional adaption condition than in the non-adaptive comparison group [22], but also significantly higher ratings for the HRI concepts of anthropomorphism and animacy [23]. In order to study the benefits and limitations of the single components of the approach as well as their mutual substitutability, the explicit and implicit emotional control variables are now evaluated in a comparative study as stand-alone conditions (explicit vs. implicit emotional adaption). Thereby, the single effects of each control variable are analyzed in comparison to the effects achieved by the full emotional adaption approach and the non-adaptive condition. Thus, in the following, the experimental studies are summarized and presented in a combined way with four different experimental conditions:

1) Full Emotional Adaption: The main group, in which full emotional adaption to the mood of the user is applied using both emotional control variables: explicitly by answering with the similarity statement “me too” in a social subdialog asking for the mood of the user, and implicitly by means of a PAD-bias during task-related interaction.

2) Explicit Emotional Adaption: In this condition, the persuasiveness of explicit emotional adaption is evaluated stand-alone, by only adapting to the user with the similarity statement “me too” in the social subdialog prior to task-related interaction. During task-related interaction EDDIE acts in an emotional way according to its task-success, but no implicit emotional adaption by a PAD-bias is applied.

3) Implicit Emotional Adaption: This condition evaluates the influence of implicit emotional adaption stand-alone, independent from explicit emotional adaption. In order to isolate the effects of the PAD-bias, small talk in terms of the social subdialog is completely skipped. Thus, possible effects triggered by the social subdialog even without applying a similarity statement, e.g. rapport, are excluded. Accordingly, only task-related interaction is applied in this condition, where EDDIE shows emotional facial and verbal expressions according to its task-success, additionally biased by shifted base-PAD values towards the mood of the user for the entire interaction.

4) Non-Adaptive: In this condition no emotional adaption is applied. In order to provide an identical and comparable interaction process to the full- and explicit emotional adaption conditions, and to reveal possible stand-alone effects of non-adaptive small talk in direct comparison to the adaptive small talk of the explicit adaption condition (both without a PAD-bias), the subjects are approached with a social subdialog, asking for their mood. However, EDDIE answers with a neutral ”ok” instead of the similarity statement “me too”. During the game, EDDIE shows emotional reactions according to its success in the game, but no PAD-bias towards the mood of the user is applied.

An overview of the tested experimental conditions and emotional control variables is given in Tab. 4.

Table 4 Overview on experimental conditions and variables testing explicit & implicit emotional adaption

Experimental Conditions	Emotional Control Variable	
	Similarity Statement (explicit)	PAD-bias (implicit)
Full Emotional Adaption	yes	yes
Explicit Emotional Adaption	yes	no
Implicit Emotional Adaption	no	yes
Non-Adaptive	no	no

For all groups of subjects, additional factors influencing helpfulness are tested by pre-interaction questionnaires to be balanced before the evaluation of the approach - namely stress (reducing helpful behavior) and dispositional empathy (increasing helpful behavior). After the interaction the subject can choose to either leave the robot and fill in the follow-up questionnaires, or to stay longer and help the robot with another task.

The goal of the study is to reveal if the approach of emotional adaption leads to significantly higher helpfulness towards the robot. For this purpose, specific assumptions and hypotheses have to be tested and fulfilled.

5.1 Assumptions & Hypotheses

In human-human interaction, only the combination of high empathy and an impression of similarity to the person in need of help leads to high helpfulness when easy means of escape are given (see Tab. 1). Since this combination has to be achieved by the presented approach, the following key assumptions have to be fulfilled:

A1) Correct interpretation of emotional output modalities: Since it is essential for the experiment, that the combination of both emotional output modalities, facial and verbal expressions, is interpreted correctly by the participants, a pretest was conducted prior to the experiment:

By presenting EDDIE, showing the six basic emotions (joy, sadness, anger, surprise, disgust, fear) to 20 staff members of Technische Universität München (TUM), a rough measure of the quality of the implementation could be achieved. Each way of conveying the emotion (visual or audio) was shown on its own and combined in random order. The pretest not only revealed that the test subjects were able to roughly assign the correct PAD values to the respective emotions by filling in the SAM-scale after each presentation, but were also able to reliably identify the key-emotions used in the experiment for task-related interaction (happiness, sadness, surprise) by filling in the emotion, they believed EDDIE to show, see Tab. 5.

Table 5 Pretest-results on human recognition rates for emotional facial and verbal expressions, evaluated in a pretest stand-alone (visual or audio), and in combination [%] according to [23].

	Audio	Video	Combined
Joy	75	75	**85**
Sadness	75	90	**95**
Anger	40	65	75
Surprise	45	90	**85**
Disgust	5	20	20
Fear	30	85	85

A2) Empathy is sufficiently high in all groups of subjects: Previous work revealed that the animation of facial expressions in a socially motivated emotional way creates significantly more empathy in users towards a robot than the animation in a non-emotional way, see Sec. 2.3. All experimental conditions, including the non-adaptive comparison group, provide socially motivated emotional facial expressions according to the task-success of the robot during the question-response game. Thus, it is hypothesized that for all experimental conditions high empathy towards the robot is induced during the interaction. Thereby, it is important to distinguish this situationally induced type of empathy from dispositional empathy that indicates the general affinity on empathy of the users. In order to proof the hypothesized situationally induced empathy, a questionnaire testing for dispositional empathy is filled in by the subjects prior to HRI, and a questionnaire evaluating situational empathy is filled in after the interaction.

A3) Easy means of escape: In order to provide “easy means of escape”, special care was taken to assure the subjects that the experiment is finished, but on the other hand assured that they brought enough time to help: All of them were told to reserve at least 40 minutes for the experiment - with the real duration normally not being more than 20 minutes altogether. Easy means of escape, in terms of providing the subjects with a possibility to leave the situation and thus avoid helpful behavior towards the robot, are given in all groups, since the robot states the end of the experiment and offers each participant to leave the experiment alternatively.

Under fulfilled assumptions, first studies revealed a significant increase in helpfulness towards the robot, as well as raised user-ratings for the concepts of anthropomorphism and animacy in the full emotional adaption condition compared to the non-adaptive condition [22, 23]. In this article, a comparative study is introduced, incorporating two new experimental conditions, where emotional adaption is split up into its components. Thus, only explicit or implicit emotional adaption is applied in order to reveal which of the two developed control variables (similarity statement vs. PAD-bias) is more effective with regard to persuasion than the other, or if only the combination of both variables leads to increased helpfulness. Furthermore, by comparing the results of the non-adaptive comparison group with those achieved by the explicit emotional adaption group, the effects of small talk as applied in the social subdialog are investigated, since these experimental conditions only differ with regard to the use of explicit emotional adaption (“ok” vs. “me too”). In other words, potential effects in helpfulness can be directly traced back to the use of the explicit emotional control variable, the similarity statement, in an isolated way independent of other small talk effects.

The following section describes the experimental design and the measures used in each phase of the experiment.

5.2 Experimental Design & Measures

For the experimental setup a quiet room with controlled lighting conditions is chosen. The robotic head is placed on a table to be at approximately eye-level with the participants. Participants are seated in front of the robot, with a microphone placed in front of them on the table to ensure a low error rate in speech recognition. The instructor greets the person, gives a short introduction on the task and hands out the pre-interaction questionnaires. To avoid that the participants are influenced by the instructor, he leaves the room as soon as the proband finishes the questionnaires, and returns not sooner than the follow-up questionnaires have to be provided. Fig. 6 shows the setup of the interaction.

The experiment consists of five phases, which are varied according to the four conditions over the different groups of subjects:

1) Pre-Interaction Questionnaires on dispositional empathy (all), stress (all), prior knowledge of the Akinator game (all), and the SAM-scale to capture the current mood of the subjects (all).

2) Social Subdialog: Variations according to the explicit emotional control variable, the similarity statement: “Me too” (full emotional adaption group & explicit emotional

Fig. 6 Experimental Setup of the interactive part [23]

adaption group), skipping of the social subdialog (implicit emotional adaption group), and the neutral statement: “Ok” (non-adaptive group).

3) Bonding-Game: Variations according to the implicit emotional control variable, the PAD-bias: emotional facial and verbal expressions according to the task-success (explicit emotional adaption group & non-adaptive group), and additionally shifted the by the PAD-bias (full emotional adaption group & implicit emotional adaption group).

4) Picture labeling: Additional task on a voluntary basis to measure helpfulness towards the robot (all).

5) Follow-up Questionnaires on induced situational empathy (all), and the Godspeed questionnaires [3] evaluating user experience with regard to the perception of the robot.

An overview of the emotional control variables, used in the related experimental phases *2) Social Subdialog* and *3) Bonding-Game* is given in Tab. 6.

Table 6 Overview on the emotional control variables, used in the experimental groups at the related phases for testing explicit & implicit emotional adaption

Experimental Group	Experimental Phase	
	Social Subdialog (explicit)	Bonding-Game (implicit)
Full Emotional Adaption	“me too”	PAD-bias
Explicit Emotional Adaption	“me too”	no PAD-bias
Implicit Emotional Adaption	–	PAD-bias
Non-Adaptive	“ok”	no PAD-bias

In the following, the five phases and used measures are explained more detailed.

5.2.1 Pre-Interaction Questionnaires

Firstly, the subjects fill in two different questionnaires testing for dispositional empathy and stress, state whether they know Akinator or not, and rate their current mood on the SAM-scale. The questionnaire fitting for the purpose of measuring dispositional empathy, is the Toronto Empathy Questionnaire (TEQ), presented in [55].

The TEQ consists of 16 self-assessing items, which can be rated between 0 (for an answer of ’never’) and 4 points (for an answer of ’always’) each. Adding these items up, a minimum of 0 and a maximum of 64 points can be reached for each person, with high values representing high empathy. Similarly, statements about the current emotional state of the test person are included, filled in by the proband after the TEQ. They help to make sure no stress or time pressure alters the helpful behavior later in the experiment. The statements used are:

- I have an important appointment after this experiment
- I reserved more than enough time for this experiment
- I feel stressed at the moment
- I hope the experiment will not take too long

Each item is rated on a scale ranging from 1 (not true) to 5 (completely true). A short question afterwards covers the influence factor whether the probands already know the game, used in the following step as a means of bonding the test persons with the robot.

A prior knowledge of the game and therefore the robot’s abilities might for example influence the impression of the robot later in the follow-up questionnaires.

5.2.2 Social Subdialog

In the second phase, explicit emotional adaption is varied: The participants are split up into the four experimental groups of equal size. The subjects of the full emotional adaption group, as well as of the explicit emotional adaption group, have some small talk with the robot asking for their mood and adapting its “mood” to theirs by the similarity statement as described in Sec. 4.1. The subjects of the non-adaptive group are faced with a neutral social subdialog, that differs with respect to the answer of the robot, by being reduced to a neutral “ok” instead of the adaptive “me too”. For subjects of the implicit adaption group, this phase is completely skipped, with the robot introducing itself with “Hello, my name is EDDIE, would you like to play a game with me?”. If the subject agrees, the robot starts task-related interaction in form of an interactive person-guessing game. by using the utterance “That’s great, how about this one: You think of a person and I try to guess which one it is”? After a positive reply to the query “Please tell me, when you’re ready”, the game is started with the first question on the thought-of charakter.

5.2.3 Bonding-Game

Managing to develop empathy and similarity between the user and the robot first requires the user to interact with the robot. Therefore, the bonding-game is played to provide an interactive context for the generation of empathy, induced by the emotional animation in all experimental groups, and similarity, induced by the PAD-bias in the full emotional adaption and implicit emotional adaption group. As a communicative task the subjects play the Akinator[2] game with EDDIE: The players first have to think of a person, and EDDIE then tries to guess the person by asking questions. The users can input their answers via microphone, with the five options from the Akinator game available, and a possibility to repeat the question: “yes”, “maybe”, “I don’t know”, “probably not”, “no”, “come again?”.

During this task-related interaction, the game determines the current emotional state of the robot, that is respectively biased by the user mood, if desired. Starting out with a neutral, but friendly expression, the robot gradually becomes more self-assured when getting nearer to an answer. This is represented by a confidence-value ranging between 0% and 100%. A medium boost in confidence lightens up the robot’s emotion, while the inability to achieve a certain level of confidence after a few steps gradually worsens the robot’s mood until it shows strong discouragement. Additionally, the robot looks more focused if the confidence passes the threshold of 50%, and changes to a more surprised mood if a large boost in confidence occurs. The robot reveals its guess of the imagined person as soon as it reaches 95% of confidence or higher. The robot then congratulates the proband on finishing the “experiment”, telling the test subject that he or she was a very good gaming partner. The praise for the user is implemented on purpose - as shown in [19], complimenting the subjects increases the ease of persuading them later on, for example when asking for help in the next phase of the experiment. The subjects are told that the experiment is over, and that they were faster than expected. On the one hand, this opens up the means of escape for the test subjects: With the robot considering the experiment finished, they are no longer obliged to stay, and the basis for measuring altruistic helpfulness is set. On the other hand, there is actually enough time left for the subject to show helpful behavior within the originally expected time frame for participating the experiment.

5.2.4 Picture labeling

In the fourth phase, the test subjects get the option of either directly proceed to the last phase, or helping the robot with an object labeling-task. The object labeling-task is used to measure the helpfulness towards the robot: The amount of pictures labeled is used as an indicator for helpfulness. The robot approaches the subject with an optional job of helping the robot with an easy object labeling task, which (allegedly) will be used to improve orientation in urban environments. The task itself intentionally is an easy one: The subject has to label everyday objects, i.e., windows, doors and stairs. The simplicity of this optional task is used to make sure it is the helpfulness of the subject that influences the number of pictures labeled and not the person’s amusement or excessive demands. Additionally, in order to avoid personal amusement, the subject has to manually type in what object is presented even though there are only four different answers. Additionally, after 38 labeled pictures, the pictures start to repeat stepwise, beginning with one repeating picture per 5 presented pictures, and ending up with all five presented pictures being repeated, before the threshold of 80 labeled pictures is reached.

The robot also stresses the point that the subject faces a rather long list of pictures and is free to leave any time after the first five labeled pictures. The amount of pictures labeled is later used to measure the helpfulness: While a subject simply quitting the experiment after the bonding-game (using the easy means of escape) shows no helpfulness, one point is added to the scale for each picture labeled, up to a maximum of 80 points for labeling all 80 pictures.

5.2.5 Follow-up Questionnaires

Lastly, one questionnaire tests whether sufficient empathy towards the robot had been induced for the similarity to work. Additional questionnaires measure the user’s perception of the robot. In the concluding phase, the instructor enters again, and asks the user whether or not EDDIE was able to guess the person. Subsequently, the subjects are asked to rate four statements concerning their situational empathy towards the robot on a scale from 1 (not true at all) to 5 (completely true) [24]:

- I’m happy EDDIE has guessed my person/I’m sorry that EDDIE didn’t guess at my person
- I would have been sorry if EDDIE had not guessed my person/It would have been nice if EDDIE had guessed my person
- It would be a pity if somebody damaged EDDIE, and I would try to interfere
- I would have been proud if EDDIE had not guessed my person/I am proud that EDDIE did not guess my person

Afterwards, the subjects fill in a selection out of the Godspeed questionnaires [3]. Based on 5-point semantic differential scales, their perception of the robot on four dimensions of HRI are measured:
Anthromorphism: how natural the robot appeared
Animacy: the liveliness of the robot
Likeability: how pleasant the robot appeared
Perceived Intelligence: how the mental abilities of the robot were perceived

Results are presented in the following section.

[2] see www.akinator.com

6 Results

Results are deduced from 84 test subjects (52 male and 32 female, between 18 and 52 years with an average age of 24,8), with very different backgrounds. Since a 2x2 between-subjects design is applied, the subjects were randomly split into four groups, with 21 in the full emotional adaption group, 22 were part of the explicit emotional adaption group, while 21 experienced only implicit emotional adaption, and 20 subjects were assigned to the non-adaptive group.

6.1 Pre-Interaction Questionnaires

Tab. 7 shows the mean values for the four experimental groups, together with the respective standard deviation for the Toronto Empathy Questionnaire (TEQ). The mean values in all groups are lower than the ones presented in [55] (measuring between 43 and 45 points for male and between 44 and 49 for female participants, respectively), even when calculating in the higher amount of male participants, hinting at the fact that the test subjects had a slightly lower dispositional empathy. Since no significant difference between the groups concerning dispositional empathy, age or gender was found, no influence of dispositional results on helpfulness was found. Therefore, this factor can be ruled out for the evaluation of the results.

Table 7 Toronto Empathy Questionnaire mean scores (on a scale from 0 to 64) and standard deviations (in brackets)

Condition	TEQ Value
Full Emotional Adaption	41.19 (6.05)
Explicit Emotional Adaption	40.10 (5.40)
Implicit Emotional Adaption	40.20 (7.10)
Non-Adaptive	42.35 (6.29)

The statements used to measure the current stress factors of the subjects were individually tested for group differences, and no significant differences between the groups were found either.

Out of 84 subjects, 25 knew the Akinator game beforehand. However, prior knowledge of the game was distributed rather equally over the experimental groups with each 6 probands in the full emotional adaption group and the non-adaptive group, and 13 participants distributed over explicit and implicit emotional adaption group - no significant influence on the helpfulness or the Godspeed results was found though.

The implicit pleasure, arousal and dominance values, captured by the SAM-questionnaire and representing the mood of the users, were collected for all subjects, but only used in the full emotional adaption and implicit emotional adaption group to adapt to the mood to the subject through a PAD-bias. A trend to higher pleasure values and neutral arousal and dominance values could be observed in all experimental groups. Hence, significant differences could be ruled out between the groups concerning dispositional PAD-values.

6.2 Social Subdialog

The explicit answers to the question "How are you?" in the full emotional adaption group were rather one-sided. 17 out of 21 people answered with a variant of "I'm fine, how are you?", only 2 stuck to a rather mediocre answer, while 2 people admitted that their mood was rather bad. In the explicit emotional adaption group, 19 out of 22 stated to be in a good mood, 2 in a rather mediocre mood and one test subject answered he was in a bad mood before the experiment. For the non-adaptive group the answers were not tracked, since the robot did not adapt explicitly to these statements, but answered with "ok" in each case. The implicit emotional adaption group skipped this experimental phase.

6.3 Bonding-Game

During the game, EDDIE was able to guess at most of the thought-of persons: Out of 84 imagined figures, EDDIE was able to guess at 71. Three characters imagined were not guessed at by the robot in the full emotional adaption group and two wrong guesses were made in the non-adaptive group. The remaining eight mistakes in the groups of explicit- and implicit emotional adaption were either very difficult characters (Schroedinger's cat, god), or result of misunderstandings. Neither the fact that a test subject knew the game before (for example altering expectations) nor the fact whether EDDIE guessed at the person correctly had a significant ($\alpha < 0.05$) influence on the later empathy questionnaire, the Godspeed dimensions or the helpfulness towards the robot.

6.4 Picture Labeling

For the helpfulness measure, the collected values ranged from zero points for not helping the robot at all, to 80 points for completely finishing the task. In the full emotional adaption group, the average number of labeled pictures led to the highest mean value for helpfulness of 53.28 (SD 6.36). The subjects of the explicit emotional adaption group resulted in an average number of 48.64 labeled pictures (SD 6.36), and while a mean value of 34.62 (SD 6.78) was reached by the implicit emotional adaption group. The lowest mean value for helpfulness was achieved by the non-adaptive group with 32.35 (SD 6.72) labeled pictures.

Although all groups are not normally distributed, an analysis of variance (ANOVA) is used to find significant effects of the experimental factors (implicit vs. explicit emotional adaption) on helpfulness: Since all groups are of (nearly) equal size, the ANOVA shows high robustness to this violation of premises. Thus, no significant change in results compared to non-parametric tests is to be expected [56]. Further, post hoc T-tests are used to find more detailed differences between the four groups.

Firstly, an univariate two-way ANOVA is conducted in order to test the effects of the two factors (independent variables): 1) explicit emotional adaption (similarity statement: yes/no) versus 2) implicit emotional adaption (PAD-bias: yes/no) on helpfulness (dependent variable), measured by the number of labeled pictures. A significant effect of explicit emotional adaption on helpfulness ($F = 6.150$, $p = .015$) is revealed. No effect is found for implicit emotional adaption, and no significant interaction was found between the factors explicit and implicit emotional adaption. Further, no influence of dispositional empathy, as well as of situational empathy, is given as covariates.

Subsequently, to get a more refined analysis, T-tests are conducted to make detailed post hoc comparisons between the conditions. Setting the significance level to $\alpha < 0.05$, T-tests showed a significant difference ($t = 2.167$, $p = .036$) between the full emotional adaption group and the non-adaptive group, where several people used the easy means of escape and did not help the robot at all. Hence, the expected increase in helpfulness for the full emotional adaption group proved to be tangible during the statistic analysis.

As a trend, a nearly significant ($t = 1.8$, $p = .086$) increase in helpfulness was found in the explicit emotional adaption group compared to the non-adaptive group. Similarly, a nearly significant decrease was observed in the implicit emotional adaption group in comparison to the full emotional adaption group ($t = -1.9$, $p = .063$). Two subjects had difficulties in understanding the robot, which lead to an alteration in the experience for them. These test subjects also showed significantly higher dispositional empathy in the TEQ, casting doubt on the fact the high helpfulness they showed was the result of empathy and similarity induced by the experiment. Discarding them accordingly, the helpfulness in the implicit emotional adaption group compared to the full emotional adaption becomes significantly lower, with $t = -2.2$ and $p = .038$. Apart from that, discarding these two subjects, does not reveal any further differences in the results.

Accordingly, a comparative ranking of helpfulness is deduced, starting with the lowest mean values in picture labeling for the non-adaptive group, increasing means over implicit and explicit emotional adaption, up to a significant higher helpfulness in the full emotional adaption group, where both, implicit and explicit control variables are applied, see Fig. 7.

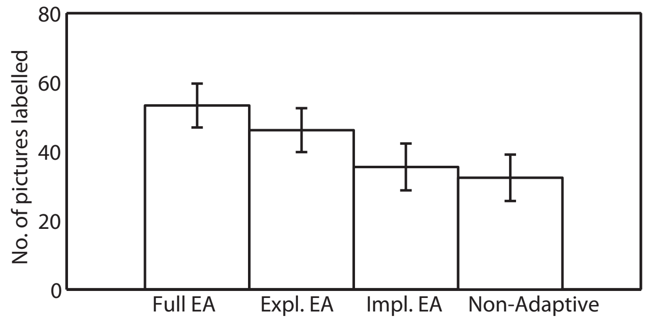

Fig. 7 Ranking of helpfulness measure means from lowest helpfulness in the comparison group to highest helpfulness in the emotional adaption group.

Since the data, gained from the picture labeling task, was not normally distributed, Figs. 8, 9, 10 and 11 show the actual distributions of experimental data for helpfulness in all experimental groups.

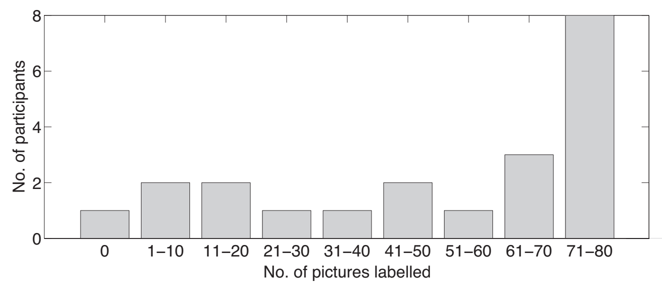

Fig. 8 Distribution of data in the full emotional adaption group

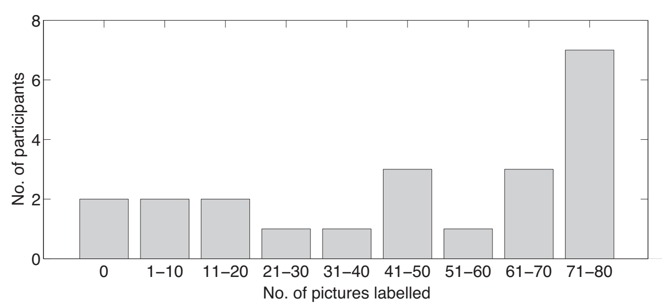

Fig. 9 Distribution of data in the explicit emotional adaption group

The actual data-distributions show pairwise similarities: The full- and explicit emotional adaption groups show a very similar low distribution of subjects, varying around 2, who

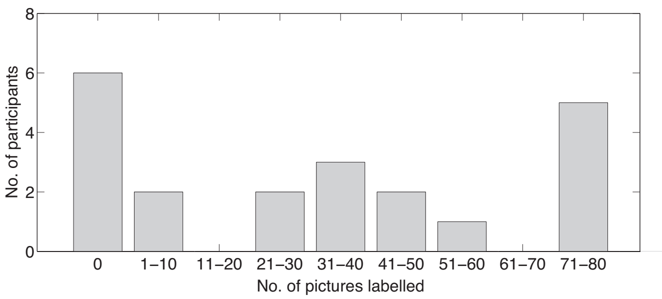

Fig. 10 Distribution of data in the implicit emotional adaption group

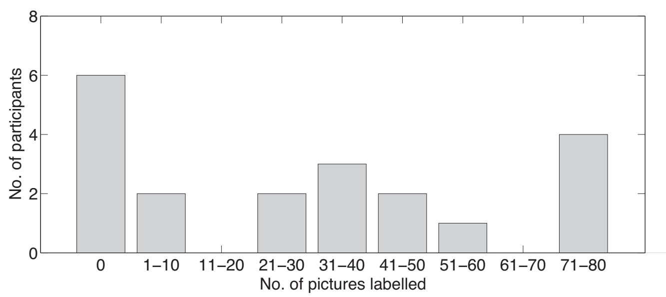

Fig. 11 Distribution of data in the non-adaptive group

stopped helping the robot before 70 pictures have been labeled. The majority of subjects (8 for full emotional adaption, and 7 for explicit emotional adaption) continued to help the robot until the maximum of 71-80 pictures was reached, although the pictures started to repeat after 38 labeled pictures, as can be seen in the peaks of Fig. 8 and 9.

In contrast, the implicit emotional adaption and non-adaptive groups show the same high amount of subjects who used the easy means of escape and did not help the robot at all, with a peak of 6 participants for both groups. Another identical peak can be observed starting from 21 until 60 labeled pictures, where in both groups 8 subjects stopped helping the robot while some pictures started to repeat with a firstly repeated picture no. 39. Nevertheless, some participants (5 in the implicit emotional adaption group and 4 in the non-adaptive group) continued helping the robot with labeling up to 71-80 pictures which is nearly half of the subjects that showed the maximum amount of help in the conditions of full- and explicit emotional adaption.

6.5 Follow-up Questionnaires

With all the Godspeed dimensions and the situational empathy being normally distributed, the ANOVA is used to reveal the effects of explicit versus implicit emotional adaption as well as possible interaction effects of dispositional/situational empathy. Post hoc T-tests ($\alpha < 0.05$) are used to test for detailed group differences. Statistical analysis reveals significant differences, similar to the results of picture labeling. Tab. 8 shows the mean values and total scores of the selected Godspeed questionnaires. Scores are ranging from 1 (very low) to 5 (very high).

As a first step, a multivariate two-way ANOVA is employed to reveal the effects of the two factors similarity statement (explicit independent variable) and PAD-bias (implicit independent variable) on the four Godspeed dimensions as dependent variables: anthropomorphism, animacy, likeability, and perceived intelligence. Dispositional and situational empathy are used as covariates. Again, results reveal highly significant effects of explicit emotional adaption on anthropomorphism ($F = 7.013$, $p = .010$), and animacy ($F = 20.941$, $p = .000$), as well as a marginally significant effect on perceived intelligence ($F = 3.9688$, $p = .05$). No interaction effects between explicit and implicit emotional adaption are found, and no influence of dispositional and situational empathy on the ratings of the godspeed dimensions are revealed.

Accordingly, post hoc T-tests showed significant differences ($\alpha < 0.05$) between the groups for the anthromorphism ($t = 2.216$, $p = 0.033$) and animacy ($t = 3.298$, $p = .002$) dimensions: The probands from the full emotional adaption group considered the robot to be more humanlike and more attentive than the test subjects in the non-adaptive group. The explicit emotional adaption group also shows much better results than the non-adaptive group: Both, the anthromorphism and the animacy dimensions, are significantly higher ($t = 2.0$ and $p = .049$ for anthromorphism, $t = 3.3$ and $p = .002$ for animacy). On the other hand, animacy is significantly lower in the implicit emotional adaption group compared with full emotional adaption ($t = 3.0$, $p = .004$). However, no correlation was found between these two Godspeed dimensions and the high helpfulness in the groups of full- and explicit emotional adaption. No group differences can be determined for perceived intelligence.

A ranking of all experimental groups for the significant differences in the dimensions of anthropomorphism and animacy is depicted in Fig. 12 and 13.

An univariate two-way ANOVA shows no significant effects of implicit versus explicit emotional adaption (independent variables) on situationally induced empathy (dependent variable). The mean values and standard deviations for situational empathy are depicted in Tab. 9 in comparison to the values of the conditions in previous work [24].

According to the results of previous work (see Sec. 2.3), empathy towards a robot could be raised by showing facial expressions in an emotional and socially adaptive way to the user. In order to fulfill the assumption *A2) Empathy is sufficiently high in all groups of subjects* given in Sec. 5.1, the level of empathy, achieved in previous work, has to be sustained. Since there is no significant difference between all experimental groups and the SMM-condition of previous work, assumption *A2)* can be regarded as fulfilled.

Table 8 Godspeed results (on a Likert-scale from 1 to 5) and standard deviations (in brackets)

Dimension	Group			
	Full-Adapt.	Expl.-Adapt.	Impl.-Adapt.	Non-Adaptive
Anthropomorphism	**3.13** (0.76)	**3.07** (0.72)	2.73 (0.76)	2.36 (0.69)
Animacy	**3.82** (0.58)	**3.76** (0.58)	3.21 (0.59)	3.18 (0.56)
Likeability	3.90 (0.59)	3.93 (0.58)	3.81 (0.78)	3.83 (0.80)
Perceived Intelligence	3.73 (0.58)	3.69 (0.58)	3.52 (0.60)	3.46 (0.54)
Total score	3.63(0.51)	3.61 (0.50)	3.32 (0.53)	3.27(0.50)

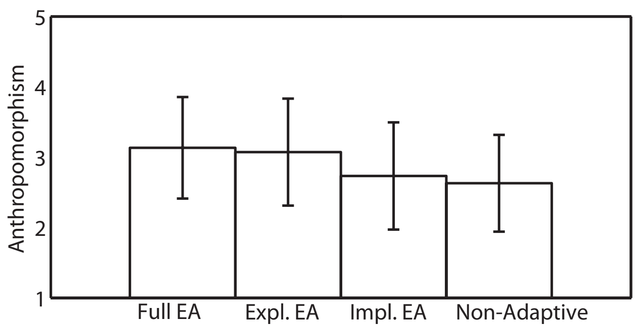

Fig. 12 Ranking of anthropomorphism measure means from lowest anthropomorphism in the non-adaptive group to highest anthropomorphism in the full emotional adaption group.

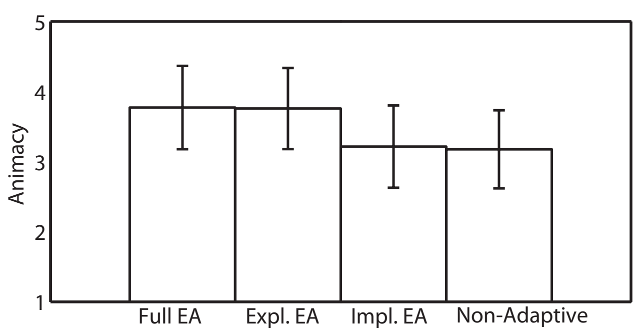

Fig. 13 Ranking of animacy measure means from lowest animacy in the non-adaptive group to highest animacy in the full emotional adaption group.

In the following, the results are summed up and discussed.

6.6 Discussion

The results show that dispositional factors like stress or differences in dispositional empathy can be ruled out over all experimental groups, since no group differences were found on these dimensions, and thus, occurred in a balanced way for all groups. Apart from few exceptions, the current mood, indicated by the subjects, was rather one-sided in a slightly positive way. Thus, in most cases, pleasure was the adapted dimension for explicit and implicit emotional adaption. Prior knowledge of the game, as well as the success of EDDIE did not influence the significance of the results. Easy means of escape are provided by the experimental design. Since no significant group differences with mean values around 4 in all groups of a maximum of 5 could be observed, situationally induced empathy can be regarded as sufficiently high and distributed equally over the experimental groups. Hence, all assumptions, defined for the approach to work, are fulfilled.

Table 9 Situationally induced Empathy (on a Likert-scale from 1 to 5) and standard deviations (in brackets), compared to the conditions of neutral-, mirror-, and Social Motivation Model (SMM) of previous work

Experiment groups	Empathy
Full Emotional Adaption	3.94 (0.67)
Explicit Emotional Adaption	4.10 (0.65)
Implicit Emotional Adaption	4.11 (0.67)
Non-Adaptive	4.13 (0.70)
Neutral	3.10 (1.30)
Mirror	3.70 (1.10)
SMM	**4.40** (0.80)

As deduced from the significant group differences in picture labeling, the participants confronted with full emotional adaption show higher helpfulness towards the robot than the participants of the non-adaptive group. Additionally, the ANOVA revealed a significant effect for the persuasiveness of explicit emotional adaption on helpfulness. On the one hand, a nearly significant increase in helpfulness could be observed for the explicit emotional adaption group, compared to the non-adaptive group, pointing to the increased persuasive power, compared to a neutral small talk (without similarity statement). On the other hand, a nearly significant decrease of helpfulness was detected for the implicit emotional adaption group, compared to the full emotional adaption group, where both emotional control variables, the similarity statement and the PAD-bias were applied, pointing to the fact that implicit emotional adaption stand-alone is not a persuasive emotional control variable, as also seen in the lack of ANOVA-effects. However, only the combination of both, explicit and implicit emotional adaption, leads to significantly increased mean values between the groups. Identically to the effects on helpfulness, the explicit similarity statement showed significant effects on anthropomorphism and animacy, but not on situationally induced empathy.

Accordingly, the question arises, why the persuasiveness of the explicit emotional adaption component is highly effective as a stand-alone emotional control variable. As outlined in Sec. 2.2, the phenomenon of “grounding” leads to better communication results in natural language dialog by establishing a shared contextual knowledge between the interlocutors. Since the non-adaptive group did not result in similar high helpfulness as the explicit emotional adaption group, this can only be traced back to the similarity statement in the course of the social subdialog as the only difference between these experimental conditions. Thus, the impression evokes, that an explicit similarity statement may establish a feeling of similarity as common ground between the interlocutors, that cannot be achieved by non-adaptive small talk alone. The resulting effect of increased helpfulness turned out to grow significantly higher when being coupled with the implicit emotional PAD-bias that recalls similarity in terms of emotional alignment in facial and verbal expressions between the dialog partners.

Previously conducted outdoor experiments on the willingness of humans to support a robot revealed the implication that the first successful communication experiences must be received by the user during the first minute of interaction [61]. Explicitly establishing common ground in form of a similarity statement prior to task-related interaction seems to meet this implication because of resulting in a first successful communication act. Additionally, the significantly increased helpfulness by an additional implicit PAD-bias during task-related interaction reconfirms the positive effects of emotional alignment, but do not seem to provide enough similarity to be established as common ground in the human interaction partner.

When analyzing the actual distributions of data for helpfulness, the same impression evokes: While the single application of explicit emotional adaption shows a highly similar distribution of helpfulness as the application of full emotional adaption, helpfulness for implicit emotional adaption is almost identically distributed as for the non-adaptive group. Nevertheless, only the combination of both emotional control variables led to significantly increased helpfulness towards the robot in the conducted experiments.

An interesting side-effect is, that in the full- and explicit emotional adaption groups, remarkably less subjects stopped the experiment when the picture sequence repeated, what could be interpreted again as symptomatic for altruism. Accordingly, the number of not helping subjects strongly decreased in comparison to the other two groups.

Whether the increased helpfulness is really due to a feeling of similarity, induced by emotional adaption, cannot be validated through the results. However, the questionnaires evaluating the anthropomorphism and animacy of the robot, again showed the same significant group differences for the benefit of explicit emotional adaption respectively. Although no direct correlations between the values for these dimensions and the number of pictures labeled could be found, there is a strong indication for anthropomorphism and animacy being the affected dimensions of the emotional adaption approach, independent from situationally induced empathy.

Summing all up, the emotional adaption approach turned out to be successful in increasing helpfulness towards a robot, thereby affecting the concepts of anthropomorphism and animacy in a significantly positive way.

7 Conclusions

A methodological approach to trigger more prosocial human reactions in terms of increased helpfulness towards a robot is deduced from social-psychological principles of human-human interaction. Unlike other state-of-the-art approaches, this approach proactively triggers a predefined target behavior for the task-benefit of a robot by transferring predictions on human behavior from Social Psychology to HRI.

The proposed approach is evaluated in a user-study, and, confirmed by significant experimental results, increases helpfulness by adapting to the mood of the user. In a first step, the current user-mood as starting point for an implicit emotional bias in facial and verbal expressions is captured by an initial self-assessment by the human subject to be extended by automatic emotion recognition modules in a later stage. An analysis of the single components of the approach revealed that explicit emotional adaption, instantiated by a similarity statement in the course of a social subdialog, turned out to be a more effective emotional control variable than implicit emotional adaption in facial expressions and prosody in speech. The combination of both, explicit and implicit emotional adaption, leads to significantly higher results in prosocial behavior towards a robot.

Future work will evaluate the generalizability of the developed approach in a fully-automated way in outdoor experiments with the robotic platform IURO, that uses a differently designed head, but controlled in the same way as the EDDIE-head.

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References

1. Asteriadis, S., Tzouveli, P., Karpouzis, K., Kollias, S.: Estimation of behavioral user state based on eye gaze and head pose - application in an e-learning environment. Multimedia Tools and Applications **41**(3), 469–493 (2009)
2. Backs, R.W., J. K. Lenneman J.M. Wetzel, P.G.: Cardiac measures of driver workload during simulated driving with and without visual occlusion. Human Factors **45**(4), 525–538 (2003)
3. Bartneck, C., Kulic, D., Croft, E.: Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. International Journal of Social Robotics **1**(1), 71–81 (2009)
4. Batson, C.D., Duncan, B.D., Ackermann, P., Buckley, T., Birch, K.: Is empathic emotion a source of altruistic motivation? Journal of Personality and Social Psychology **40**, 290–302 (1981)
5. Berger, D.: Clinical empathy. Jason Aronson, Inc., Northvale (1987)
6. Bickmore, T.W., Cassell, J.: Small talk and conversational storytelling in embodied interface agents. In: Proc. of the AAAI Fall Symposium ”Narrative Intelligence”. Cape Cod, MA. (1999)
7. Bradley, M.M., Lang, P.J.: Measuring emotion: The self-assessment manikin and the semantic differential. Journal of Behavior Therapy and Experimental Psychiatry **25**(1), 49 – 59 (1994)
8. Carston, R.: The explicit/implicit distinction in pragmatics and the limits of explicit communication. International Review of Pragmatics **1**(1), 35–62 (2009)
9. Castelfranchi, C.: Modelling social action for ai agents. Artificial Intelligence **103**, 157–182 (1998)
10. Castelfranchi, C.: Grounding social action and phenomena in mental representations. In: Advances in Cognitive Science: Learning, Evolution, and Social Action. Proc. of IWCogSc-10- ILCLI, pp. 93–112 (2010)
11. Clark, H.H., Schaefer, E.F.: Contributing to discourse. Cognitive Science **13**, 259–294 (1989)
12. Cowie, R., Douglas-Cowie, E., Tsapatsoulis, N., Votsis, G., Kollias, S., Fellenz, W., Taylor, J.: Emotion recognition in human-computer interaction. IEEE Signal Processing Magazine **18**(1), 32 – 80 (2001)
13. Cramer, H., Goddijn, J., Wielinga, B., Evers, V.: Effects of (in)accurate empathy and situational valence on attitudes towards robots. In: Proceedings of the 5th ACM/IEEE international conference on human-robot interaction - HRI ’10, pp. 141–142. ACM Press, New York, USA (2010)
14. Damm, O., Malchus, K., Hegel, F., Jaecks, P., Stenneken, P., Wrede, B., Hielscher-Fastabend, M.: A computational model of emotional alignment. In: Proc. of 5th Workshop on Emotion and Computing. Berlin (2011)
15. Ekman, P.: Universals and cultural differences in facial expressions of emotion. In: J. Cole (ed.) Proc. of the Symposium on Motivation, vol. 19, pp. 207–283. University of Nebraska (1971)
16. Ekman, P., Friesen, W.: Investigator’s Guide: Part two. Facial Action Coding System. Consulting Psychologists Press, Palo Alto, CA (1978a)
17. Elliott, C., Rickel, J., Lester, J.: Artificial Intelligence Today: Recent Trends and Developments, *Lecture Notes in Computer Science*, vol. 1600, chap. Lifelike Pedagogical Agents and Affective Computing: An Exploratory Synthesis, pp. 195–211. Springer Berlin Heidelberg (1999)
18. Fischer, A.H., van Kleef, G.A.: Where have all the people gone? a plea for including social interaction in emotion research. Emotion Review **2**(3), 208–211 (2010)
19. Fogg, B.: Persuasive Technology: Using Computers to Change What We Think and Do, chap. 5: Computers as Persuasive Social Actors, pp. 89–120. The Morgan Kaufmann Series in Interactive Technologies. Morgan Kaufmann Publishers, San Francisco (2003)
20. Frey, D., Irle, M. (eds.): Theorien der Sozialpsychologie, Band II: Gruppen-, Interaktions- und Lerntheorien, vol. 2. Verlag Hans Huber (2002)
21. Gentner, D.: International Encyclopedia of the Social and Behavioral Sciences, chap. Psychology of Mental Models, pp. 9683–9687. Elsevier (2002)
22. Gonsior, B., Buß, M., Sosnowski, S., Wollherr, D., Kühnlenz, K., Buss, M.: Towards transferability of theories on prosocial behavior from social psychology to hri. In: Proc. of the IEEE Int. Workshop on Advanced Robotics and its Social Impacts (ARSO), pp. 101–103. Munich (2012)
23. Gonsior, B., Sosnowski, S., Buß, M., Wollherr, D., Kühnlenz, K.: An emotional adaption approach to increase helpfulness towards a robot. In: Proc. of the IEEE Int. Conf. on Intelligent Robots and Systems (IROS), pp. 2429–2436 (2012)
24. Gonsior, B., Sosnowski, S., Mayer, C., Blume, J., Radig, B., Wollherr, D., Kühnlenz, K.: Improving aspects of empathy and subjective performance for hri through mirroring facial expressions. In: Proc. of IEEE Int. Symp. on Robot and Human Interactive Communication (RO-MAN), pp. 350–356. Atlanta, GA, USA (2011)
25. Heise, D.R.: Agent culture: human-agent interaction in a multicultural world, chap. 6: Enculturating agents with expressive role behavior, pp. 127–142. Lawrence Erlbaum (2004)
26. Kaliouby, R., Picard, R., Baron-Cohen, S.: Annals of the New York Academy of Sciences, *Progress in Convergence*, vol. 1093, chap. Affective Computing and Autism, pp. 228–248 (2006)
27. Kiesler, S., Goetz, J.: Mental models and cooperation with robotic assistants. In: Proc. of the ACM Conference on Human Factors in Computing Systems (CHI). ACM SIGCHI (2006)
28. Kim, K.H., Bang, S.W., Kim, S.R.: Emotion recognition system using short-term monitoring of physiological signals. Medical and Biological Engineering and Computing **42**(3), 419–427 (2004)
29. Kraut, R.E., Johnston, R.E.: Social and emotional messages of smiling: An ethological approach. Journal of Personality and Social Psychology **37**(9), 1539–1553 (1979)
30. Krebs, D.: Empathy and altruism. Journal of Personality and Social Psychology **32**, 1134–1146 (1975)
31. Kühnlenz, K., Sosnowski, S., Buss, M.: Impact of animal-like features on emotion expression of robot head eddie. Advanced Robotics **24**(8-9), 1239–1255 (2010)
32. Liu, C., Conn, K., Sarkar, N., Stone, W.: Online affect detection and robot behavior adaptation for intervention of children with autism. IEEE Transactions on Robotics **24**(4), 883–896 (2008)
33. Mayer, C., Sosnowski, S., Kühnlenz, K., Radig, B.: Towards robotic facial mimicry: System development and evaluation. In: Proc. of IEEE Int. Symp. on Robot and Human Interactive Communication (Ro-Man), pp. 198 – 203 (2011)
34. Mayer, C., Wimmer, M., Eggers, M., Radig, B.: Facial expression recognition with 3d deformable models. In: Proc. of the 2nd Int. Conf. on Advancements Computer-Human Interaction (ACHI). Springer (2009)
35. McQuiggan, S., Lester, J.: Modeling and evaluating empathy in embodied companion agents. International Journal of Human-Computer Studies **65**(4), 348–360 (2007)
36. Mehrabian, A.: Silent Messages: Implicit Communication of Emotions and Attitudes. Wadsworth, Belmont, California (1981)
37. Mehrabian, A.: Pleasure-arousal-dominance: A general framework for describing and measuring individual differences in Temperament. Current Psychology **14**(4), 261–292 (1996)
38. Nakagawa, K., Shiomi, M., Shinozawa, K., Matsumura, R., Ishiguro, H., Hagita, N.: Effect of robot’s active touch on people’s motivation. In: Proc. of IEEE Int. Conf. on Human-Robot Interaction (HRI) (2011)

39. Nakagawa, K., Shiomi, M., Shinozawa, K., Matsumura, R., Ishiguro, H., Hagita, N.: Effect of robot's whispering behavior on people's motivation. International Journal of Social Robotics **5**(1), 5–16 (2013)
40. Niewiadomski, R., Ochs, M., Pelachaud, C.: Expressions of empathy in ECAs. Intelligent Virtual Agents pp. 1–8 (2008)
41. Nourbakhsh, I.R., Bobenage, J., Grange, S., Lutz, R., Meyer, R., Soto, A.: An affective mobile robot educator with a full-time job. Artificial Intelligence **114**(12), 95 –124 (1999)
42. Ochs, M., Pelachaud, C., Sadek, D.: An empathic virtual dialog agent to improve human-machine interaction. In: Padgham, Parkes, Müller, Parsons (eds.) Proceedings of the 7th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2008), pp. 89–96. Estoril, Portugal (2008)
43. Paiva, A., Dias, J., Sobral, D., Aylett, R., Woods, S., Hall, L., Zoll, C.: Learning By Feeling: Evoking Empathy With Synthetic Characters. Applied Artificial Intelligence **19**(3-4), 235–266 (2005)
44. Picard, R.: Affective Computing. MIT Press, Cambridge (1997)
45. Pickering, M.J., Garrod, S.: Toward a mechanistic psychology of dialogue. Behavioral and Brain Sciences pp. 1–58 (2004)
46. Prendinger, H., Ishizuka, M.: The emphatic companion: A character-based interface that adresses users' affective states. Applied Artificial Intelligence **19**(3-4), 267–285 (2005)
47. Rani, P., Liu, C., Sarkar, N., Vanman, E.: An empirical study of machine learning techniques for affect recognition in humanrobot interaction. Pattern Analysis and Applications **9**(1), 58–69 (2006)
48. Reitberger, W., Meschtscherjakov, A., Mirlacher, T., Scherndl, T., Huber, H., Tscheligi, M.: A persuasive interactive mannequin for shop windows. In: Proc. of Persuasive 09, The 4th Int. Conf. on Persuasive Technology, Article No. 4. ACM (2009)
49. Riek, L.: Wizard of oz studies in hri: A systematic review and new reporting guidelines. Journal of Human Robot Interaction **1**(1), 119–136 (2012)
50. Riek, L., Robinson, P.: Real-time empathy: Facial mimicry on a robot. In: in Workshop on Affective Interaction in Natural Environments (AFFINE) at the International ACM Conference on Multimodal Interfaces. ACM, pp. 1–5 (2008)
51. Scheeff, M., Pinto, J., Rahardja, K., Snibbe, S., Tow, R.: Experiences with sparky, a social robot. Socially Intelligent Agents **3**, 173–180 (2002)
52. Schröder, M.: The german text-to-speech synthesis system mary: A tool for research, development and teaching pp. 365–377 (2001)
53. Schroeder, M.: Dimensional emotion representation as a basis for speech synthesis with non-extreme emotions. In: Proc. of Workshop on Affective Dialogue Systems, pp. 209–220 (2004)
54. Sosnowski, S., Kuehnlenz, K., Buss, M.: Eddie - an emotion display with dynamic intuitive expressions. In: Proc. IEEE Int. Symp. on Robot and Human Interactive Communication (RO-MAN) (2006)
55. Spreng, R.N., McKinnon, M., Mar, R., Levine, B.: The toronto empathy questionnaire: Scale development and initial validation of a factor-analytic solution to multiple empathy measures. Journal of Personality Assessment **91**(1), 62–71 (2009)
56. Tabachnick, B., Fidell, L.: Experimental Design Using ANOVA. Duxbury Applied Series. Brooks/Cole (2007)
57. Tapus, A., Mataric', M.J.: Emulating Empathy in Socially Assistive Robotics Empathy in Socially Assistive Robotics. In: In AAAI Spring Symposium on Multidisciplinary Collaboration for Socially Assistive Robotics. Palo Alto, Stanford, U.S.A. (2007)
58. Thomas, A.P., Bull, P., Roger, D.: Conversational exchange analysis. Journal of Language and Social Psychology **1**(2), 141–156 (1982)
59. Traum, D.R.: A computational theory of grounding in natural language conversation. Ph.D. thesis, University of Rochester, Computer Science (1994)
60. Wallhoff, F., Rehrl, T., Mayer, C., Radig, B.: Realtime face and gesture analysis for human-robot interaction. In: Proc. of the SPIE, Society of Photo-Optical Instrumentation Engineers Conf. (2010)
61. Weiss, A., Igelsbck, J., Tscheligi, M., Bauer, A., Kühnlenz, K., Wollherr, D., Buss, M.: Robots asking for directions: The willingness of passers-by to support robots. In: Int. Conf. on Human-Robot Interaction (HRI), pp. 23–30 (2010)
62. Young, J.E., Hawkins, R., Sharlin, E., Igarashi, T.: Toward acceptable domestic robots: Apllying insights from social psychology. Int. Journal of Social Robotics (IJSR) **1**(1), 95–108 (2009)
63. van der Zwaan, J., Dignum, V., Jonker, C.: A BDI Dialogue Agent for Social Support : Specification of Verbal Support Types (Extended Abstract) Categories and Subject Descriptors. In: Conitzer, Winikoff, Padgham, van der Hoek (eds.) Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2012). Valencia, Spain (2012)

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