A Computational Model of Empathy: Empirical Evaluation

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***Abstract*—Empathy can be defined as the ability to perceive and understand others' emotional states. Neuropsychological evidence has shown that humans empathize with each other to different degrees depending on factors such as their mood, personality, and social relationships. Although artificial agents have been endowed with features such as affect, personality, and the ability to build social relationships, little attention has been devoted to the role of such features as factors that can modulate their empathic behavior. In this paper, we present and discuss the results of an empirical evaluation of a computational model of empathy which allows a virtual human to exhibit different degrees of empathy. Our model is supported by psychological models of empathy and is applied and evaluated in the context of a conversational agent scenario.**

I. Introduction and Related Work

In human social interaction, empathy has been shown to play a crucial role in cooperative and prosocial behaviors such as helping and caring [1]. Neuropsychological findings [2] substantiated that empathic brain responses can be modulated through a variety of factors, e.g., a person's mood, personality, and social relationships. Humans thus empathize with each other to different degrees depending on such modulation factors.

Research on empathic artificial agents substantiates the role of empathy in enhancing artificial agents' social behavior. Brave et al. [3] show that empathic agents are perceived as more likable, trustworthy, and caring. Paiva et al. [4] found that empathic virtual humans can evoke empathy in children and can thus teach them to deal with bullying situations. Bickmore et al. [5] demonstrate that a virtual human's empathic behavior also contributes to its ability to build and sustain long-term socio-emotional relationships with human partners.

By contrast, Becker et al. [6] found that a virtual human's empathic emotions can have negative effects. For instance, in a competitive card game scenario, empathic emotions can increase arousal and induce stress in an interaction partner. In line with humans' ability to empathize with each other to different degrees, a modulation of a virtual human's empathic behavior through factors such as its mood, personality, and relationship to its interaction partner, would allow for a more adequate empathic behavior in the agent across different interaction scenarios.

Although providing artificial agents with features such as affect, personality, and the ability to build social relationships is the subject of increasing interest, little attention has been devoted to the role of such features as factors that can modulate their empathic behavior. In their computational models of empathy, Rodrigues et al. [7] and Ochs et al. [8] considered different degrees of empathy by modulating the intensity of the empathic emotion. In [7], the intensity of the empathic emotion is determined by the modulation factors *similarity*, *affective link*, *mood*, and *personality* while in [8] it is determined by the modulation factors *liking* and *deservingness* (cf. [9]). Regarding the evaluation of an artificial agent's empathic behavior, in previous research, evaluations have been based on either two conditions, *non-empathic* vs. *empathic* (e.g., [7]) or on three conditions, *non-empathic*, *empathic*, and *non-congruent empathic* (e.g., [8] and [6]).

In this paper, we present and discuss the results of an empirical evaluation of a computational model of empathy which allows a virtual human to exhibit different degrees of empathy. Supported by psychological models of empathy, our model is based on three processing steps [10]: First, the *Empathy Mechanism* produces an empathic emotion. Second, the *Empathy Modulation* modulates the empathic emotion. Third, the *Expression of Empathy* triggers the virtual human's multimodal behavior through the modulated empathic emotion. The empathy model is applied and evaluated in the context of a conversational agent scenario involving the virtual humans MAX [11] and EMMA [12] and a human interaction partner. Within this scenario, the model is realized for EMMA thus allowing her to empathize with MAX's emotions during his interaction with the human partner. As compared to the previous research by Rodrigues et al. [7] and Ochs et al. [8], our model not only modulates the intensity of an empathic emotion but also its related emotion category. In this regard, we follow Hoffman's [1] emphasis that an empathic response need not be a close match to the affect experienced by the other, but can be any emotional reaction compatible with the other's situation. Furthermore, we evaluated our model based on three different conditions that distinguished different degrees of empathy. As such, we allow for a more fine-grained evaluation of how our model and its underlying parameters affect participants' perception of EMMA's empathic behavior.

The paper is structured as follows: In Section II, we briefly introduce our approach to model empathy for a virtual human. In Section III, we present and discuss the results of an empirical evaluation of the empathic behavior generated by our model. Finally, in Section IV, we summarize the main aspects underlying our approach and give an outlook on future work.

II. A Computational Model of Empathy

Similar to the virtual human MAX [11], EMMA has a cognitive architecture composed of an emotion simulation module

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[13] and a Belief-Desire-Intention (BDI) module [11]. The emotion simulation module consists of a dynamics/mood component for the calculation of the course of emotions and moods over time and their mutual interaction, and of a Pleasure, Arousal, Dominance (PAD) space in which emotion categories are located and their intensity values can be calculated. The emotion simulation module outputs values of pleasure, arousal, and one of two possible values of dominance (dominant vs. submissive) as well as intensity values of emotion categories. Our computational model of empathy is integrated within the emotion simulation module and is based on three processing steps briefly introduced in the following (more details on the technical realization of the model as well as on its theoretical foundation are available in previous work [10]).

A. Empathy Mechanism

Hoffman [1] introduces *facial mimicry* as an empathy mechanism and defines it as the process involving the *imitation* of another's facial expressions, which triggers an afferent *feedback* eliciting the same feelings in oneself as those of the other. Following this, in our model, the *Empathy Mechanism* consists of an *internal imitation* of perceived facial expressions and results in an *emotional feedback* that represents the perceived emotional state. This is based on the use of a *shared representational system* (cf. [2]). That is, our virtual human uses the same facial expression repertoire to express its own emotions as well as to understand emotions from perceived facial expressions.

EMMA has a face which replicates 44 AUs implemented in line with the Facial Action Coding System (FACS) [14]. In an empirical study, human participants rated randomly generated facial expressions of EMMA with PAD values [12]. As a result, three dimensional regression planes showing the meaning of each AU in PAD space were obtained. By combining all planes of all AUs a repertoire of facial expressions arranged in PAD space is reconstructed. Accordingly, using her own AUs and their intensity functions (regression planes) in PAD space, EMMA maps a perceived facial expression to AUs with corresponding intensity values (*internal imitation*) and subsequently infers its related emotional state as a PAD value (*emotional feedback*). The inferred PAD value is represented by an additional reference point in EMMA's PAD emotion space. Its related emotion category as well as its corresponding intensity value can thus be inferred (more details on the technical realization of facial mimicry are available in [10]).

The empathic emotion is elicited after detecting a fast and salient change in the other's emotional state that indicates the occurrence of an emotional event. That is, with respect to a predetermined short time interval T, the difference between inferred PAD values corresponding to the time-stamps t_{k-1} and t_k, with $t_k - t_{k-1} <= T$, is calculated as $|PAD_{t_k} - PAD_{t_{k-1}}|$. If this exceeds a predefined saliency threshold $TH1$ or if $|PAD_{t_k}|$ exceeds a predefined saliency threshold $TH2$, then the emotional state PAD_{t_k} and its related emotion category represent the empathic emotion. The predefined thresholds can be interpreted as representing the virtual human's responsiveness to the other's situation. Once an empathic emotion is elicited, the following processing step *Empathy Modulation* is triggered.

B. Empathy Modulation

The modulation of the empathic emotion is realized within PAD space of the virtual human's emotion simulation module. Accordingly, at each point in time an empathic emotion is elicited, the following equation is applied:

$$empEmo_{t,mod} = ownEmo_t + (empEmo_t - ownEmo_t) \cdot (\sum_{i=1}^{n} p_{i,t} \cdot w_i) / (\sum_{i=1}^{n} w_i) \quad (1)$$

The value $empEmo_{t,mod}$ represents the modulated empathic emotion. The value $ownEmo_t$ represents the virtual human's own emotional state as the modulation factor *mood*. The value $empEmo_t$ represents the non-modulated empathic emotion resulting from the previous processing step, the *Empathy Mechanism*. The values $p_{i,t}$ represent modulation factors in addition to the mood factor. The values w_i represent assigned values of weights for the modulation factors $p_{i,t}$. The values $p_{i,t}$ represent arbitrary predefined modulation factors that can have values ranging in $[0, 1]$. Such modulation factors are for example, *liking* and *familiarity*. As proposed by OCC [9], *liking* can be represented by values ranging in $[-1, 1]$ from maximum dislike to maximum like where the value 0 represents neither like nor dislike. Following this, *familiarity* can be represented by values ranging in $[0, 1]$ from non-familiar to most-familiar. Note that only the impact of positive values of $p_{i,t}$ is considered in our model.

We define the degree of empathy as the degree of similarity between the modulated empathic emotion and the non-modulated one. Thus, the degree of empathy is represented by the distance between $empEmo_{t,mod}$ and $empEmo_t$ within PAD space (see Fig. 1). That is, the closer $empEmo_{t,mod}$ to $empEmo_t$, the higher the degree of empathy. The less close $empEmo_{t,mod}$ to $empEmo_t$, the lower the degree of empathy.

Following Rodrigues et al. [7], in our model, the virtual human is more sensitive to the empathic emotion when its emotional state is more similar to the empathic emotion. The virtual human is more resistant to the empathic emotion when its emotional state is less similar to the empathic emotion. That is, the closer the virtual human's own emotional state $ownEmo_t$ to the empathic emotion $empEmo_t$ the higher the degree of empathy. The less close the virtual human's own emotional state $ownEmo_t$ to the empathic emotion $empEmo_t$ the lower the degree of empathy. With regard to the modulation factors $p_{i,t}$, the higher their value of weighted mean, the closer the modulated empathic emotion $empEmo_{t,mod}$ to the non-modulated empathic emotion $empEmo_t$ and the higher the degree of empathy. The lower their value of weighted mean, the less close the modulated empathic emotion $empEmo_{t,mod}$ to the non-modulated empathic emotion $empEmo_t$ and the lower the degree of empathy.

According to Hoffman [1], an empathic response to the other's emotion should be more appropriate to the other's situation than to one's own and need not be a close match to the affect experienced by the other, but can be any emotional reaction compatible with the other's situation. Further, according to the thesis of the dimensional theories [15], emotions are related to one another in a systematic manner and their relationships can be represented in a dimensional model. Accordingly, the modulated empathic emotion $empEmo_{t,mod}$ is facilitated only if it lies in an immediate neighborhood to the non-modulated empathic emotion $empEmo_t$. Hence, for each emotion category located within PAD space of the emotion simulation module, we defined a so called *empathy facilitation region* as a box surrounding the emotion category. For example, Fig. 1 shows the PA space of positive dominance of the emotion simulation module with the defined *empathy facilitation region* for the emotion category *annoyed*. As depicted in Fig. 1 (middle), the modulated empathic emotion $empEmo_{t,mod}$ has as related emotion category *concentrated* (neutral emotional state) and the non-modulated empathic emotion $empEmo_t$ has as related emotion category *annoyed*. Accordingly, once the modulated empathic emotion $empEmo_{t,mod}$ enters the *empathy facilitation region* defined for *annoyed*, it is facilitated or otherwise it is inhibited (e.g., Fig. 1, left). Within the *empathy facilitation region*, the modulated empathic emotion $empEmo_{t,mod}$ represents an empathic response that is compatible with the other's situation (cf. [1]). Thus, the virtual human is allowed to react with an emotion that is of a different type (but compatible) with the partner's emotion. The degree of empathy increases or decreases within the *empathy facilitation region* and equals 0 outside this region. Once the modulated empathic emotion is facilitated, the next processing step *Expression of Empathy* is triggered.

C. Expression of Empathy

The PAD value of the modulated empathic emotion triggers EMMA's corresponding facial expression [12] and modulates her speech prosody [16]. The higher the arousal value of the modulated empathic emotion, the higher the frequencies of EMMA's eye-blinking and breathing. Triggering other modalities, e.g., verbal utterances depends on the scenario's context.

III. Empirical Evaluation

The empirical evaluation of the empathy model is performed in the context of a conversational agent scenario. In this scenario, the virtual humans MAX and EMMA can engage in a multimodal small talk dialog with a human partner using speech, gestures, and facial behaviors [10]. The emotions of both agents can be triggered positively or negatively by the human partner through, e.g., compliments or politically incorrect verbal utterances. During interaction of MAX with the human partner, EMMA follows the conversation by directing her attention to the speaking agent. When attending to MAX, EMMA's empathy process is triggered in response to MAX's facial expression of emotion. The purpose of the empirical evaluation is to investigate how the virtual human's behavior produced by our empathy model is perceived and interpreted by human participants. In this regard, we examined the following hypotheses:

- **H1**: EMMA's expression of empathy is perceivable by the participants.
- **H2**: EMMA's expressed degree of empathy is perceivable by the participants.
- **H3**: the human participants acknowledge different values of relationship between EMMA and MAX according to EMMA's expressed degree of empathy.
- **H4**: EMMA is perceived as more likable the higher the value of her expressed degree of empathy.

A. Design and Procedure

We designed 24 dialog interactions to be used in a repeated measures design. The interactions were between EMMA, MAX, and a human partner, who we called Lisa. At the beginning of each of the 24 dialog interactions, the virtual humans are in a neutral emotional state. In each of the 24 dialog interactions, Lisa begins by greeting EMMA and then praising her. Consequently, EMMA's positive emotional state of *happiness* is triggered. Simultaneously, EMMA greets Lisa and thanks her for being kind. Then Lisa greets MAX but proceeds to insult him. Thus, MAX's negative emotional state of *anger* is triggered. Simultaneously, MAX responds with a negative verbal utterance such as "Lisa, you are horrible!". Meanwhile, EMMA empathizes with MAX to different degrees depending on her mood and her defined relationship to MAX. Note that MAX's facial expression of *anger* is interpreted by EMMA as showing the emotional state *annoyed* (cf. Section II-A). Accordingly, the elicited empathic emotion has as related emotion category *annoyed* (see Fig. 1).

For each of the 24 dialog interactions, we designed three different conditions where we manipulated within-subjects the value of EMMA's relationship to MAX and thus her degree of empathy with MAX. In all conditions, EMMA was in the same positive mood after being praised by Lisa. Thus, the mood modulation factor was constant across all conditions. Since the focus was not on the interaction of several relationship modulation factors, only the factor *liking* was manipulated. The conditions are as follows:

1) EMMA's value of *liking* toward MAX equals 0. Accordingly, her modulated empathic emotion is inhibited and her value of degree of empathy also equals 0. In this case, EMMA continues expressing her own positive emotional state of happiness triggered by Lisa's praising expression. We call this condition the **neutral liking condition** (see Fig. 1, left).
2) EMMA's value of *liking* toward MAX equals 0.5. Accordingly, her modulated empathic emotion is facilitated and has as its related emotion category *concentrated*. In this case, EMMA expresses the modulated empathic emotion. Hence, her values of *liking* and degree of empathy are higher than in the first condition. We call this condition the **medium liking condition** (see Fig. 1, middle).
3) EMMA's value of *liking* toward MAX equals 1. Accordingly, her modulated empathic emotion equals the non-modulated one which has as its related emotion category *annoyed*. In this case, EMMA expresses the non-modulated empathic emotion and her value of degree of empathy is maximal. Hence, her values of *liking* and degree of empathy are higher than in the first and second condition. We call this condition the **maximum liking condition** (see Fig. 1, right).

In all three conditions, EMMA's degree of empathy was expressed by her facial expression and speech prosody while the verbal utterance was the same across all conditions. Thus, after MAX's response to Lisa, EMMA also responded with a

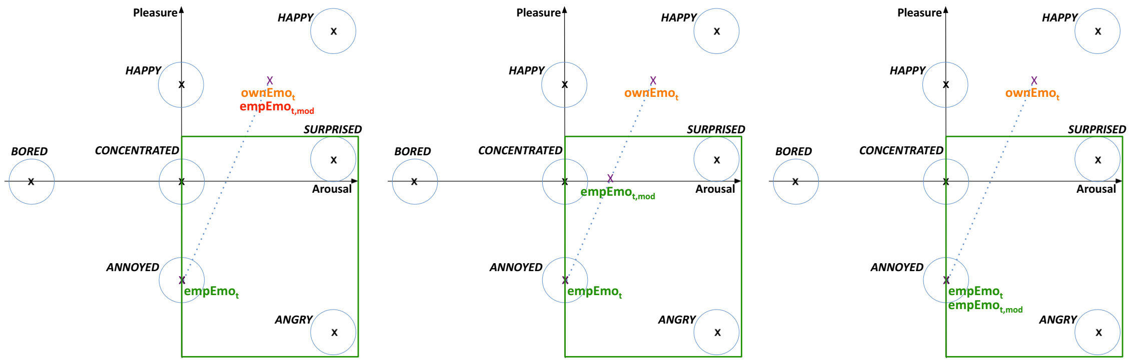

Fig. 1. EMMA's modulated empathic emotion, $empEmo_{t,mod}$, in PAD space of positive dominance. $ownEmo_t$ refers to EMMA's own emotional state, $empEmo_t$ refers to the non-modulated empathic emotion, and the box represents the *empathy facilitation region* defined for the emotion category *annoyed*.

negative verbal utterance such as "You are nasty to MAX!". EMMA's and MAX's breathing, eye blinking, and conversational gestures are deactivated in all three conditions.

A total of 72 videos of the 24 Dialog interactions in the three conditions were recorded. In order to assign the video recordings to participants, we constructed three experimental lists following the Latin Square design such that each dialog appeared in each list in only one condition. A total of 30 participants took part in the experiment, with each list assigned to 10 participants. The 24 videos contained in a list were presented in a random order to each corresponding participant. The participants' age ranged between 21 and 38 years.

To test our four hypotheses, each participant was asked to complete a questionnaire after each watched video. The questionnaire comprises five items that were rated using a 7-point Likert scale (see Table I).

Measure	Questionnaire item	Scale
Expression of empathy (**H1**)	"In the last frame of the video, EMMA's face shows: " "In the last frame of the video, EMMA's speech prosody is: "	-3 = very negative mood +3 = very positive mood -3 = very negative +3 = very positive
Degree of empathy (**H2**)	"In this video, EMMA is: "	-3 = very cold to MAX +3 = feeling with MAX
Values of relationship (**H3**)	"In this video, EMMA has: "	-3 = very negative relationship to MAX +3 = very strong relationship to MAX
Likability (**H4**)	"In this video, EMMA is overall: "	-3 = very unlikable +3 = very likable

TABLE I. SCHEMATIC OVERVIEW OF THE QUESTIONNAIRE FILLED OUT BY THE PARTICIPANTS. THE QUESTIONNAIRE ITEMS WERE RATED USING A 7-POINT LIKERT SCALE RANGING FROM -3 TO $+3$.

B. Results

For the analysis of the collected rating data, we started by calculating the mean rating by condition for each of the five questionnaire items for participants and items (i.e. videos) separately. Next, we performed an omnibus repeated measures one-way ANOVA using participants and items as random effects. The results of the omnibus ANOVA show a significant effect of condition for all five questionnaire items.

To assess how the conditions differ from each other, we next performed a series of planned pairwise comparisons by participants and items. As the participant and item comparisons yielded similar results, for simplicity's sake, we present the results for the participants' analyses. To address the concern that some of our data may not be normally distributed, we also performed non-parametric tests (Wilcoxon signed-rank test and Mann-Whitney test). In the following, we present the results of the pairwise comparisons for each of the hypotheses **H1**, **H2**, **H3**, and **H4** (cf. Table I and Section III).

*1) Expression of Empathy (**H1** in Table I):* Regarding the ratings of EMMA's facial expression in the last frames of the presented videos, the mean values show that EMMA's facial expression was rated as showing a positive mood in the neutral liking condition ($M = 0.883$), as showing a slightly negative mood in the medium liking condition ($M = -0.438$), and as showing a more negative mood in the maximum liking condition ($M = -1.554$); (see Fig. 2). The pairwise comparisons show that the three conditions were rated as significantly different from each other ($p < .001$).

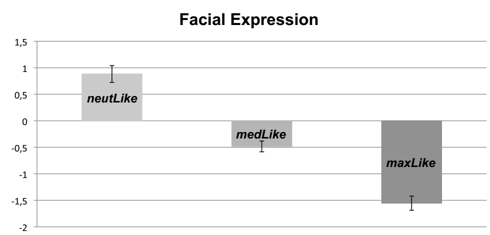

Fig. 2. Mean values and their standard errors for facial expression.

Regarding the ratings of EMMA's speech prosody in the last frames of the presented videos, the mean values show that EMMA's speech prosody was rated as slightly positive in the neutral liking condition ($M = 0.521$), as slightly negative in the medium liking condition ($M = -0.550$), and as more negative in the maximum liking condition ($M = -1.592$); (see Fig. 3). As for the ratings of EMMA's facial expression, the pairwise comparisons show that the three conditions were rated as significantly different from each other ($p < .001$).

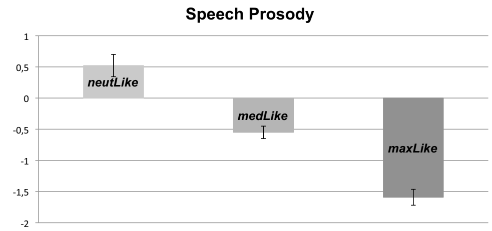

Fig. 3. Mean values and their standard errors for speech prosody.

*2) Degree of Empathy (**H2** in Table I):* The mean values show that EMMA was rated as slightly feeling with MAX in the neutral liking condition ($M = 0.458$) and as progressively more feeling with MAX in the medium liking condition ($M = 0.992$) and the maximum liking condition ($M = 1.608$) respectively (see Fig. 4). As for EMMA's expression of empathy, the pairwise comparisons show that the three conditions were rated as significantly different from each other ($p < .001$).

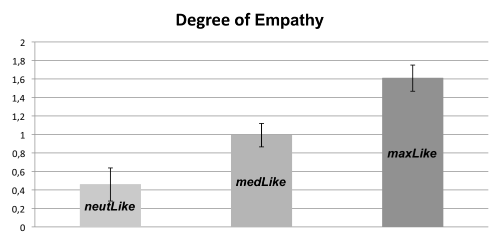

Fig. 4. Mean values and their standard errors for degree of empathy.

*3) Values of Relationship (**H3** in Table I):* The mean values show that EMMA's value of relationship to MAX was rated as slightly positive in the neutral liking condition ($M = 0.325$) and as progressively more positive in the medium liking condition ($M = 0.888$) and the maximum liking condition ($M = 1.442$) respectively (see Fig. 5). As for EMMA's expression of empathy and her expressed degree of empathy, the pairwise comparisons show that the three conditions were rated as significantly different from each other ($p < .001$).

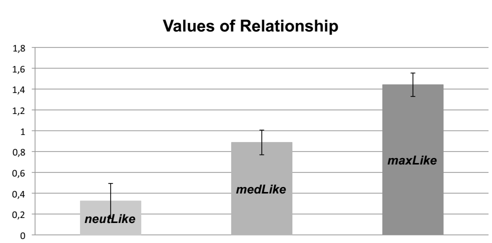

Fig. 5. Mean values and their standard errors for values of relationship.

*4) Likability (**H4** in Table I):* The mean values show that EMMA was rated as slightly likable in the neutral liking condition ($M = 0.250$) and as progressively more likable in the medium liking condition ($M = 0.500$) and the maximum liking condition ($M = 0.746$) respectively (see Fig. 6). The pairwise comparisons show a significant difference only between the neutral liking and the maximum liking conditions ($p < .05$).

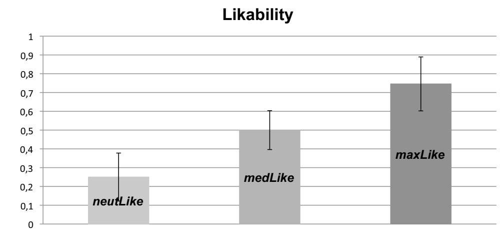

Fig. 6. Mean values and their standard errors for likability.

C. Discussion

The results of evaluating EMMA's expression of empathy (facial expression and speech prosody, Fig. 2 and 3) show its appropriate recognition as positive in the neutral liking condition, and as progressively more negative in the medium and maximum liking conditions respectively. Hence, the results confirm hypothesis **H1**, that EMMA's expression of empathy is perceivable by the participants, and suggest the appropriate modeling of EMMA's facial expressions and speech prosody.

The results of evaluating EMMA's expressed degree of empathy with MAX (Fig. 4) show that it was rated as significantly higher in the maximum liking condition than in the other two conditions, and as significantly higher in the medium liking condition than in the neutral liking condition. Hence, the results confirm hypothesis **H2**, that EMMA's expressed degree of empathy is perceivable by the participants. These findings further substantiate the theoretical assumption underlying our model that empathy occurs to different degrees. Furthermore, the results show that EMMA's facial expression and speech prosody are reliable indicators of her different degrees of empathy, thus providing further support for their appropriate modeling.

Descriptively, the more negative participants rated EMMA's expression of empathy (Fig. 2 and 3), the more they rated EMMA as empathic (Fig. 4). Thus, the more EMMA's expression of empathy was similar to MAX's emotional expression, the more EMMA was rated as empathic. This is in line with our definition of the degree of empathy as the degree of similarity between one's empathic emotion and the other's perceived emotion (cf. Section II-B). That is, the more similar one's empathic emotion to the other's perceived emotion, the higher the degree of empathy.

The results of evaluating EMMA's different values of relationship with MAX (Fig. 5) show that it was rated as significantly higher in the maximum liking condition than in the other two conditions, and as significantly higher in the medium liking condition than in the neutral liking condition. Hence, the results confirm hypothesis **H3**, that human participants acknowledge different values of relationship between EMMA and MAX according to EMMA's expressed degree of empathy. Descriptively, participants' ratings of EMMA' degree of empathy (Fig. 4) seem to covary with their ratings of her value of relationship to MAX. This is in line with our definition of the impact of relationship modulation factors such as *liking* or *familiarity* in our model. That is, the higher the values of such modulation factors, the higher the similarity between the empathic emotion and the other's perceived emotion, the higher the degree of empathy. These findings further substantiate the theoretical assumption underlying our proposed model that empathy is modulated by several factors such as the relationship between the empathizer and the observed other. Again, the results also show that EMMA's facial expression and speech prosody are reliable indicators of her different values of relationship to MAX thus providing further support for their appropriate modeling.

The results of evaluating EMMA's likability (Fig. 6) show that EMMA was rated as somewhat likable in the neutral liking condition, and as progressively more likable in the medium liking and maximum liking conditions respectively. However, a significant difference was found only between the neutral liking and maximum liking conditions. These results only partially support hypothesis **H4**, that EMMA is perceived as more likable the higher the value of her expressed degree of empathy. In this regard, follow-up analyses revealed between-participants differences. While most of the participants reported having rated EMMA's likability on the basis of her degree of empathy with MAX, others however, rated EMMA's likability on the basis of, e.g., her positive emotions in the presented video. That is, the more EMMA was friendly to Lisa the more she was rated as likable. Accordingly, they may have interpreted EMMA's expression of a positive emotion together with a verbal expression of empathy in the neutral liking condition as a more convenient way to communicate to Lisa the inappropriateness of her behavior toward MAX.

IV. Conclusion

In this paper, we presented the results of an empirical evaluation of a computational model of empathy. This model allows a virtual human to exhibit different degrees of empathy, an aspect that has received little attention in previous research on empathic artificial agents. Supported by psychological models of empathy, our model is based on three processing steps [10]: *Empathy Mechanism*, *Empathy Modulation*, and *Expression of Empathy*. Regarding *Empathy Modulation*, regions of immediate neighborhood for each emotion category located in PAD space were defined where a modulated empathic emotion from different type but compatible with the non-modulated one is facilitated. Accordingly, we defined the degree of empathy as the degree of similarity between a modulated empathic emotion and a non-modulated one within these defined regions. In this regard, we rely on the thesis of the dimensional emotion theories that emotions are related to one another in a systematic manner and that their relationships can be represented in a dimensional model [15]. Hence, we exploited the assumed relationships between emotions in PAD space. Note that the choice of the values of parameters underlying our model such as the values of the *empathy facilitation regions* is a matter of design and evaluation.

The results of the empirical evaluation of our model show that EMMA's expression of empathy was appropriately recognized and that it was a reliable indicator of her degree of empathy and her value of relationship to MAX. These findings support our claim that the empathic behavior generated by our model concurs with underlying theories, and also further substantiates them. A highlight is that our empirical evaluation is one of the first in this field to consider three conditions showing different degrees of empathy, thus allowing for a more fine-grained evaluation of the output of the model as well as of its underlying parameters.

In future work, the evaluation of human participant's perception of other modulation factors such as the mood modulation factor and how they impact the degree of empathy could be considered. Furthermore, evaluation of the model in other context scenarios could be performed to further investigate the adequacy of the generated empathic behavior.

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