# Modeling Empathy for a Virtual Human: How, When and to What Extent?

# (Extended Abstract)

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## ABSTRACT

Going along the questions of how, when and to what extent does empathy arise in humans, we propose an approach to model empathy for EMMA – an Empathic MultiModal Agent – based on three processing steps: First, the *Empathy Mechanism* by which an empathic emotion is produced. Second, the *Empathy Modulation* by which the empathic emotion is modulated. Third, the *Expression of Empathy* by which EMMA's modulated empathic emotion is expressed through her multiple modalities. The proposed model is integrated in a conversational agent scenario involving the virtual humans MAX and EMMA.

## Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous

## General Terms

Algorithms, Measurement, Design, Human Factors, Theory

## Keywords

Affect and personality, Empathy, Human-Agent/Agent-Agent Interaction

## 1. INTRODUCTION

While significant advances have been made in modeling empathy for virtual humans, the modulation of the empathic emotion through factors like the empathizer's mood and relationship to the other [4] is either missing or only the intensity of the empathic emotion is modulated. Following [6], the empathic response to the other's emotion does not need to be in a close match with the affect experienced by the other, but can be any emotional reaction compatible with the other's condition. Thus, in our work the modulation factors not only affect the intensity of the empathic emotion but also its related type. Since a dimensional approach is believed to be more convenient to model and analyse the subtletly, complexity, and continuity of affective behavior, our empathy model is realized in EMMA's Pleasure-Arousal-Dominance (PAD) emotion space [1]. The empathy model is supported and motivated by psychological models of empathy (see [2] for more details).

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## 2. THE EMPATHY MODEL

***Empathy Mechanism*** EMMA's face replicates 44 Action Units (AUs) implemented following [5]. As a result of an empirical study [3] three dimensional non-linear regression planes for each AU in PAD space were obtained. By combining all planes of all AUs a facial expressions repertoire is reconstructed.

Using her own AUs and their activation functions (regression planes) in PAD space, EMMA maps a perceived facial expression to AUs with corresponding activation values and subsequently infers its related emotional state as a PAD value. The inferred PAD value is represented by an additional reference point in EMMA's PAD emotion space. Its related primary emotion as well as its corresponding intensity value can thus be inferred.

The empathic emotion is elicited after detecting a fast and at the same time salient change in the other's emotional state that indicates the occurrence of an emotional event or if the other's emotional state is perceived as salient. With respect to a predetermined short time interval $T$, the difference between inferred PAD values corresponding to the timestamps $t_{k-1}$ 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 $TH$ or if $|PAD_{t_k}|$ exceeds a predefined saliency threshold $TH'$, then the current emotional state $PAD_{t_k}$ and its related primary emotion represent the empathic emotion.

***Empathy Modulation*** The modulation is realized by applying the following equation each time $t$ an empathic emotion is elicited:

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

The value $empEmo_{t,mod}$ represents the modulated empathic emotion. The value $ownEmo_t$ represents EMMA's current emotional state and thus the modulation factor *empathizer's mood*. The value $empEmo_t$ represents the non-modulated empathic emotion. The values $p_{i,t}$ represent arbitrary predefined modulation factors that could have values ranging in $[0,1]$ such as *liking* and *familiarity*. *Liking* could be represented by values ranging in $[-1,1]$ from *disliked* to *most-liked*. The value 0 represents neither *liked* nor *disliked*. In this paper, only positive values of *liking* are considered.

We designate the *degree of empathy* as the distance between $empEmo_{t,mod}$ and $empEmo_t$ (see Fig. 1). 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*.

The impact of the modulation factors on the degree of empathy is as follows: The closer $ownEmo_t$ to $empEmo_t$, the higher the *degree of empathy*. The less close $ownEmo_t$ to $empEmo_t$, the lower

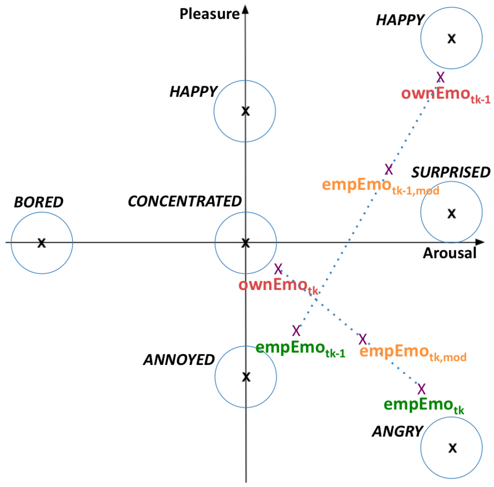


**Figure 1: EMMA's PA emotion space of high dominance. The primary emotions *happy*, *surprised*, *angry*, *annoyed*, *bored*, and the neutral state *concentrated* are located at different PA values.**

the *degree of empathy*. The impact of the modulation factors $p_{i,t}$ is calculated through a weighted mean of their current values at timestamp $t$. E.g., *liking* can be defined as having more impact on the *degree of empathy* than *familiarity* and thus can be weighted higher. The higher the value of $p_{i,t}$'s weighted mean, the higher the *degree of empathy*. The lower the value of $p_{i,t}$'s weighted mean, the lower the *degree of empathy*.

Following [6], the empathic response to the other's emotion can be any emotional reaction compatible with the other's condition. Therefore, $empEmo_{t,mod}$ is *facilitated* only if its related primary emotion is defined as close enough to that of $empEmo_t$. Primary emotions defined as close to $empEmo_t$'s primary emotion should represent emotional reactions that are compatible with the other's condition.

Fig. 1 shows EMMA's PA emotion space of high dominance. At the time $t_{k-1}$ EMMA's current emotion $ownEmo_{t_{k-1}}$ has as related primary emotion *happy*, $empEmo_{t_{k-1}}$ has as related primary emotion *annoyed*. The resulting $empEmo_{t_{k-1},mod}$ has as related primary emotion *surprised* which is defined as not close enough to *annoyed*. At this stage $empEmo_{t_{k-1},mod}$ is *inhibited*. At the time $t_k$ EMMA's current emotion $ownEmo_{t_k}$ is the neutral state *concentrated*, $empEmo_{t_k}$ has as related primary emotion *angry*. The resulting $empEmo_{t_k,mod}$ has as related primary emotion *annoyed* which is defined as close enough to *angry*. At this stage $empEmo_{t_k,mod}$ is *facilitated*.

***Expression of Empathy*** Based on EMMA's face repertoire, the PAD value of the modulated empathic emotion triggers EMMA's corresponding facial expression. EMMA's speech prosody [7] is modulated by the PAD value of the modulated empathic emotion. The higher the arousal value of the modulated empathic emotion, the higher the frequencies of EMMA's eye-blinking and breathing. Triggering other modalities like verbal utterances depends on the scenario's context.

## 3. SCENARIO

In a conversational agent scenario, MAX and EMMA conduct a multimodal small talk with a human partner. The emotions of both virtual humans can be triggered positively or negatively by the human partner through compliments or politically incorrect verbal expressions. In this scenario, EMMA empathizes with MAX's emotions to different degrees depending on the following factors: First, EMMA's *mood* which changes dynamically over the interaction when the human partner triggers EMMA's emotions negatively or positively. Second, EMMA's *liking* toward MAX and EMMA's *familiarity* with MAX which have predefined values that does not change dynamically over the interaction. Thus, the impact of the *mood* factor as dynamically changing over the interaction can be better perceived in this scenario. By calculating the difference of the pleasure values of MAX's perceived emotion, $P_{t_k} - P_{t_{k-1}}$, at timestamps $t_{k-1}$ and $t_k$, EMMA detects changes in MAX's pleasure value and encourages the human partner dependingly. A positive change that results in a positive pleasure value triggers an utterance like "Its great, you are so kind to MAX!". A positive change in the negative space of pleasure triggers an utterance like "Be kinder to MAX!". Analogously, verbal utterances are triggered by a negative change in pleasure.

## 4. FUTURE WORK

In future work, we aim at empirically evaluating EMMA's empathic behavior within the above introduced scenario. In particular, we will focus on the impact of EMMA's *mood*, as a modulation factor that dynamically changes over the interaction, on human subjects' perception of EMMA's empathic behavior. The evaluation will be performed to test the following hypothesis: The human partner should perceive EMMA's behavior as more adequate when she exhibits a modulated empathic behavior related to her perceived emotional state rather than when exhibiting a non-modulated one.

## 5. ACKNOWLEDGMENTS


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