An Ambient Agent Model for Group Emotion Support

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Abstract

This paper introduces an agent-based support model for group emotion, to be used by ambient systems to support teams in their emotion dynamics. Using model-based reasoning, an ambient agent analyzes the team's emotion level for present and future time points. In case the team's emotion level is found to become deficient, the ambient agent provides support to the team by proposing the team leader, for example, to give a pep talk to certain team members. The support model has been formally designed and within a dedicated software environment, simulation experiments have been performed.

1. Introduction

Within psychology, emotion is often defined as a state or process that plays a role in various cognitive processes, among which decision making and action preparation. In the multidisciplinary research of emotion, computational models of emotion can be found that are based on appraisal theory. Examples of models that have the goal to make virtual agents believable or human-like are the Affective Reasoner [1] and the EMA model [2]. Examples of cognitive models of emotion are Frijda's model [3] and the OCC model [4]. In all these models the focus lies on the individual, not on the group. Modeling group emotion based on appraisal models of emotion, can be problematic. In [5] the authors discuss the problem why appraisal models of emotion can not enforce a consistent group emotion. Today almost no literature on computational models of group emotion exists. The model of emotion contagion introduced in [6] was a first exploration in the computational modeling of group emotion. The current paper introduces a support model which is based on this emotion absorption model and therefore a first exploration in the modeling of group emotion support.

In psychological literature on emotional support models for the emotional support of victims, family of victims and patients by humans, such as grief and post-disaster counselors and doctors are proposed. Imagine a situation where a software agent can provide emotional support to humans. For example, a virtual character on the Internet providing emotional support to humans that are depressed or a software agent providing emotional support on the work floor, such as during video-conferencing or during naval warfare. The goal of this paper is to introduce a first agent-based support model for group emotion, which can be used by ambient systems to support humans within teams in their emotional responses. The idea here is that the ambient agent can analyze the team's emotional level both for present and future time points. In case the team's emotional level is found (to become) deficient, compared to a certain norm, the ambient agent can provide support to the team, for instance, by proposing the team leader to give a pep talk to a team member whose emotional level causes the group emotion to become too low.

In the description of the detailed model in the next Sections, the temporal relation a $\twoheadrightarrow$ b denotes that when a state property a occurs, then after a certain time delay (which for each relation instance can be specified as any positive real number), state property b will occur. In this language (called LEADSTO) both logical and numerical calculations can be specified, and a dedicated software environment is available to support specification and simulation; for more details see [7]. So far only one emotion at a time is analyzed in the ambient agent model, but this can easily be extended to take into account multiple emotions as long as they are considered as independent from each other. However, if also interaction between different emotions is to be addressed (for example, anger in one person affecting fear in another person), more specific work is needed, which is planned for the future.

Below, in Section 2, a detailed model of group emotion contagion is explained and formalized. Next, in Section 3, the model has been extended with an analysis process to be used by an ambient agent to analyze the (expected) dynamics of emotion contagion processes. Section 4 introduces support mechanisms which can be used by an ambient agent to support a team in keeping the group emotional level optimal. In Section 5, simulation results of the analysis and the support mechanism are shown. Finally Section 6, concludes the paper with a discussion.

2. A Model for Emotion Contagion

The emotion contagion model used in this paper has been designed as an interpretation of the bottom-up approach where group emotion can be seen as the sum of its parts [8]. It distinguishes multiple factors that

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influence emotion contagion processes. The model incorporates individual differences in personality traits [9]: neuroticism and extraversion (BIS and BAS, [10]). A number of aspects of the proposed computational model are distinguished that play a role in the contagion, varying from aspects related to an agent *S* sending the emotion, an agent *R* receiving the emotion, and the channel between sender *S* and receiver *R*; see Table 1.

level of the sender's emotion	q_S
level of the receiver's emotion	q_R
sender's emotion expression	ε_S
openness for received emotion	δ_R
the strength of the channel from sender to receiver	α_{SR}
a person's relevance for the group's emotion state	ρ_A
the level of the group's emotion state	q

Table 1 Aspects related to a sender S, receiver R, or both

The aspect ε_S depends on how introvert or extravert, expressive, and/or active or energetic the person is. These aspects correspond to the personality trait extraversion and sensation seeking and the underlying neural system BAS. It represents in how far a person transforms internal emotion into external expression. In this sense, an introvert person will induce a weaker contagion of an emotion than an extravert person. The aspect α_{SR} depends on the type and intensity of the contact between the two persons (e.g., distance vs attachment). The aspect δ_R indicates the degree of susceptibility of the receiver. This represents in how far the receiver allows the emotions received from others to affect the own emotion, and how flexible/persistent the person is emotionally.

The parameter α_{SR} may be related to a combination of more specific aspects such as the directness of the emotion contagion, and the relations between sender and receiver. The stronger the channel, the higher α_{SR} and the more contagion will take place. Emotion contagion is direct if the persons infecting each other with emotions are together in the same room and pay attention to each other [11]. Indirect contagion can happen when for instance the contagion between others is observed. Direct contagion is propagated stronger than indirect emotion contagion.

The aspects shown in Table 1 have been formalized numerically by numbers in the interval [*0, 1*]. In addition, the parameter γ_{SR} is used to represent the strength by which an emotion is received by *R* from sender *S*, modeled as: $\gamma_{SR} = \varepsilon_S\ \alpha_{SR}\ \delta_R$. The model works as follows: if γ_{SR} is *0*, there will be no contagion, if it is *1*, there will be a maximum strength of contagion. If γ_{SR} is not *0*, there will be contagion and the higher the value, the more contagion will take place. In a way γ_{SR} expresses the energy level with which an emotion is being expressed, transferred and received. The overall strength by which emotions from all the other group members are received by *R* in a group *G*, indicated by γ_R, is defined as $\gamma_R = \Sigma_{S\in G\setminus\{R\}}\ \gamma_{SR}$. Take weights proportional to $\varepsilon_S\alpha_{SR}$ defined by $w_{SR} = \varepsilon_S\ \alpha_{SR}\ /\ \Sigma_{C\in G\setminus\{R\}}\ \varepsilon_C\ \alpha_{CR}$ and for any $R\in G$ let $q_R^* = \Sigma_{S\in G\setminus\{R\}}\ w_{SR}\ q_S$ be the weighted combined emotion from the other agents. The set of differential equations for emotion contagion in group *G* is

$$dq_R/dt = \gamma_R\ (q_R^* - q_R)$$

for all $R\in G$. Here $\gamma_R = \Sigma_{S\in G\setminus\{R\}}\ \gamma_{SR}$ with $\gamma_{SR} = \varepsilon_S\ \alpha_{SR}\delta_R$. Notice that, in contrast to a population- or group-based model that would use aggregate variables at the group level, the model used is an *agent-based model* with variables for individual group members. This conforms to the bottom-up approach to emotion contagion known in the literature; e.g., [8].

Based on the emotion levels of the individual group members a level of the *group's emotion state* can be determined according to a certain measure. Within this measure the emotion levels of specific group members will contribute, but maybe not for each member in a comparable manner. Therefore for each group member *A* a (relative) *relevance factor*(ρ_A) is considered indicating to which extent this member is relevant for the measure of the group's emotion state, i.e.,

$$q = \Sigma_{A\in G}\, q_A\ \rho_A$$

3. The Group Emotion Analysis Model

The emotion contagion model described in Section 2 above can be used by an ambient agent to analyse the past, present and future (expected) dynamics of a team's emotion contagion processes. The main goal of the ambient agent designed is to estimate and predict the level of a given type of emotion in the group at present and future points in time and based on such an analysis propose actions whenever considered needed. The emotion considered is assumed to be a positive emotion, so when the emotion level of the group is expected to become too low, this analysis process should detect this early enough to intervene.

Concepts needed in such a model for an ambient agent concern the ambient agent's estimations of the relevant human's states at different points in time; these estimations are described by the ambient agent's observations and beliefs; in addition an assessment of the (expected) group's emotion state is needed. An assessment is generated when the group emotion level at some (future) time point is expected to be too low, compared to a certain norm (*EN*). Moreover, to model direct observation of individual emotion levels, the concept *expressed emotion level* ($\varepsilon_S\ q_A$) is used, as the emotion level that can be observed from someone's face, for example, by use of a face reader. This may differ from the emotion level in that the expressiveness factor has also effect on it.

To formalize the concepts introduced in this and the previous section, number of logical atoms are introduced that incorporate numerical representations;

see Table 2. Note that in order to generate and analyze possible temporal patterns for the future, some of the atoms have an additional time variable *T*. This is used to make predictions about future emotion states, as part of the analysis.

concept	*formalisation*
observation that person *A* has expressed emotion level *EV* at time *T*	observed(agent, has_expressed_emotion_level_at(A:AGENT, EV:REAL,T:REAL))
belief that person *A* has expressed emotion level *EV* at time *T*	belief(agent, has_expressed_emotion_level_at(A:AGENT, EV:REAL,T:REAL))
belief that person *B* has expressiveness *E*	belief(agent, has_expressiveness(B:AGENT, E:REAL))
belief that person *A* has openness for received emotion *D*	belief(agent, has_openness(A:AGENT, D:REAL))
belief that the channel from *B* to *A* has strength *C*	belief(agent, has_channel_strength(B:AGENT, A:AGENT, C:REAL))
belief that the contagion strength from *B* to *A* is *CS*	belief(agent, has_contagion_strength(B:AGENT, A:AGENT, CS:REAL))
belief that the overall contagion strength to receiver *A* is *CS*	belief(agent, has_overall_contagion_strength(A:AGENT, CS:REAL))
belief that step size is *DT*	belief(agent, stepsize(DT:REAL))
belief that person *A* has relevance *R*	belief(agent, has_relevance(A:AGENT, R:REAL))
belief that person *A* has emotion level *V* at time *T*	belief(agent, has_emotion_level_at(A:AGENT, V:REAL, T:REAL))
belief that the group emotion level at *T* is *GE*	belief(agent, group_emotion_level_at(GE:REAL, T:REAL))
belief that the group emotion norm is *EN*	belief(agent, group_emotion_norm(EN:REAL))
assessment that the deficient of the group emotion at *T* is *ED*	assessment(agent, group_emotion_deficient_at(ED:REAL, T:REAL))

Table 2 Concepts to reason about emotion contagion and their formalization

The dynamic relationships of the model to reason about emotion contagion are described and formalised as follows. Note that the beliefs on emotion expressiveness, openness, and channel strengths are assumed to be initially given and to persist (until they are changed). Moreover, a scenario is considered where at some (initial) point in time the current emotion levels of the members are estimated or observed, and from that time point onwards, the beliefs on emotion levels for subsequent time points are determined, as a form of temporal projection (or prediction).

First the role of observed expressed emotions is formalised. The agent is assumed to possess observation equipment in the form of a face reader with software that detects emotion expressions from face images. This expressed emotion *EV* results from the emotion level *V* and the expressiveness *E* by which the emotion is displayed on the face. In the model it is assumed that the expressed emotion level is formalised as the product *V*E*. Note that this means that it is assumed that the expressiveness (being a number between *0* and *1*) always reduces the level of the emotion: $EV \leq E$. In other words, this assumption excludes the situation that an emotion level is expressed that is not there (no faking of emotions). Moreover, note that in ADR2 below it is assumed that the expressiveness factor *E* is nonzero. Then under the assumptions discussed above, from an expressed emotion level *EV* the emotion level *V* itself can be determined as $V = EV/E$.

ADR1 Observing group members' expressed emotion levels

If the agent observes an expressed emotion level
then the ambient agent will believe this.

observes(agent, has_ expressed_emotion_level_at(A, V, T)) →
belief(agent, has_ expressed_emotion_level_at(A, V, T))

ADR2 Generating a belief on an emotion level from a belief on an expressed emotion level

If the agent believes that a group member has expressed emotion level *EV*
and that this group member has expressiveness *E*
then it will generate a belief that this group member has emotion level *EV/E*

belief(agent, has_ expressed_emotion_level_at(A, EV, T)) &
belief(agent, has_ expressiveness(E))
→ belief(agent, has_ emotion_level_at(A, EV/E, T))

ADR3 Generating beliefs on contagion strengths

If the ambient agent believes that *B* has expressiveness *E*
and the ambient agent believes that the channel from *B* to *A* has strength *C*
and the ambient agent believes that *A* has openness *D*
then the ambient agent will believe that the contagion strength from *B* to *A* will be *E*C*D*

belief(agent, has_expressiveness(B, E)) &
belief(agent, has_channel_strength(B, A, C)) &
belief(agent, has_openness(A, D))
→ belief(agent, has_contagion_strength(B, A, E*C*D))

ADR4 Updating beliefs on emotion levels

If $A \neq B$ and $B \neq C$ and $C \neq A$
and the ambient agent believes that *A* has emotion level *V1* at time *T*
and the ambient agent believes that *B* has emotion level *V2* at time *T*
and the ambient agent believes that *C* has emotion level *V3* at time *T*
and the ambient agent believes that the contagion strength from *B* to *A* is *CS2*

and the ambient agent believes that the contagion strength from *C* to *A* is *CS3*
and the ambient agent believes that the step size is *DT*
then the ambient agent will believe that the emotion level of *A* will be *V1+CS2*(V2-V1)*DT+CS3*(V3-V1)*DT* at time *T+DT*

```
A≠B & B≠C & C≠A &
belief(agent, has_emotion_level_at(A, V1, T)) &
belief(agent, has_emotion_level_at(B, V2, T)) &
belief(agent, has_emotion_level_at(C, V3, T)) &
belief(agent, has_contagion_strength(B, A, CS2)) &
belief(agent, has_contagion_strength(C, A, CS3)) &
belief(agent, step_size(DT))
→ belief(agent, has_emotion_level_at(A, V1+CS2*(V2-V1)*DT+
CS3*(V3-V1)*DT, T+DT))
```

An analysis also involves an assessment of the (expected) level of the group's emotion. To this end, first a belief on the group's emotion level is generated.

ADR5 Determining beliefs on the group's emotion level
If the ambient agent believes that the group members have emotion levels *V1, V2, V3*
and relevance *R1, R2, R3* respectively
then it will believe that the group's emotion level is *R1*V1+ R2*V2+R3*V3*.

```
belief(agent, has_emotion_level_at(a1, V1, T)) &
belief(agent, has_emotion_level_at(a2, V2, T)) &
belief(agent, has_emotion_level_at(a3, V3, T)) &
belief(agent, has_relevance(a1, R1)) &
belief(agent, has_relevance(a2, R2)) &
belief(agent, has_relevance(a3, R3))
→ belief(agent, group_emotion_ level_at(R1*V1+ R2*V2+R3*V3, T))
```

An assessment is generated when the group emotion level at some (future) time point is expected to be too low, compared to a certain norm. In case of a negative outcome further action may be needed, to avoid this undesired situation. The assessment includes an estimation of how much the group emotion level is too low (the *group emotion deficient*):

ADR6 Assessment of the group's emotion level
If the ambient agent believes that the group emotion level *V* at time *T* is lower than the emotion norm *EN*, then it will assess the situation as having a group emotion deficient *EN-V* at *T*.

```
belief(agent, group_emotion_ level_at( V, T)) &
belief(agent, group_emotion_norm(EN)) & V<EN
→ assessment(agent, group_emotion_ deficient_at(EN-V, T))
```

4. The Group Emotion Support Model

In the previous sections, the emotion contagion model and the analysis process based on it have been discussed. In this section, the support model is introduced that uses these models to provide intelligent support to humans in cases where the group emotion level is expected to become below a certain norm. The support model introduced here uses a heuristic approach. The idea here is that an ambient agent will reason about the proper actions that should be undertaken by the team leader to keep the group emotion level optimal. For example, it uses knowledge expressing that in case the group emotion level (e.g., relaxedness or happiness) is lower than a certain norm, certain members are to be detected that play a crucial role in a negative or positive sense and give them either a pep talk to or to increase or decrease their impact on the other group members.

When a negative assessment of the (future) group emotion state is made, then the ambient agent is assumed to propose actions to the team leader, in order to avoid such states. Some examples of possible actions are:

- giving a group member that negatively affects the emotion in the team a less central role (decreasing the emotion contagion strengths from this person)
- ask a person with a positive emotion level (for example the team leader) either to not be too open for other members (decrease the person's openness; i.e., δ_R) or to be more expressive (increase the person's expressiveness; i.e., ε_S)

Two heuristics that are applied are the following:

- *let the group members with lower emotion levels get less impact on the other members, and get more impact from the other members*
- *let the group members with higher emotion levels get more impact on the other members, and get less impact from the other members*

Here 'higher' and 'lower' can be defined as the members with highest or lowest emotion level, but also as above or under the group's emotion level. In general, two (low and high) *emotion thresholds* are assumed for this, where a specific case is that these thresholds are both equal to the group's emotion level.

For a group member under the low threshold, his or her impact on the other members can be decreased by (encouragement for) decreasing the person's expressiveness, or by decreasing the channel strengths from this person to the other members. Moreover, the person's impact from other members can be increased by increasing the person's openness, and by increasing the channel strengths from the other members. For an overview of the action options based on the two heuristics, see Table 3.

	person under low threshold	*person above high threshold*
expressiveness	decrease	increase
openness	increase	decrease
channels to others	decrease	increase
channels from others	increase	decrease

Table 3 Overview of the action options

This approach does not give indications for the adjustment extent to which such increase or decrease has to be applied. When such adjustment extents are chosen, the approach can also be combined with a feasibility ranking approach described next.

After the ambient agent generates the actions options, they have to be ranked on their (in)feasibility expressing how difficult they are to achieve, because it may happen that some action options can be easily realized whereas others are difficult to realize. The action option with the lowest infeasibility will be chosen and proposed by the ambient agent to the team leader. A realistic ranking, from the most to the least infeasible parameter, could be: 1) openness (δ_A), because it seems that this personality characteristic is difficult to change overtime; 2) expressiveness (ε_A) because this personality characteristic can be 'faked' (one can display emotions that are not experienced); 3) channel strength (α_{BA}) because it is easy to lower the channel strength's between a person and every other group member, by simply separating this individual from the group. The formalization of the concepts is given in Table 4.

concept	*formalisation*
the agent believes that the low threshold for individual emotion levels is *LT*	belief(agent, low_threshold(LT:REAL))
the agent believes that the high threshold for individual emotion levels is *HT*	belief(agent, high_threshold(HT:REAL))
the agent believes that *A* is a low emotion member	belief(agent, low_emotion_member(A:AGENT))
the agent believes that *A* is a high emotion member	belief(agent, high_emotion_member(A:AGENT))
the agent believes that the adjustment extent is *AE*	belief(agent, adjustment_extent(AE:REAL))
the agent believes that an action option is to change the value *W1* for expressiveness of *A* to *W2*	belief(agent, action_option(adjust_to(expressiveness(A:AGENT), W1:REAL, W2:REAL)))
the agent believes that an action option is to change the value *W1* for channel strength from *A* to *B* to *W2*	belief(agent, action_option(adjust_to(channel_strength(A:AGENT, B:AGENT), W1:REAL, W2:REAL)))
the agent believes that an action option is to change the value *W1* for openness of *A* to *W2*	belief(agent, action_option(adjust_to(openness(A:AGENT), W1:REAL, W2:REAL)))
the agent believes that parameter *P* has adjustment infeasibility factor *IF*	belief(agent, has_infeasibility_factor(P: PARAMETER, IF:REAL))
the agent believes that the action option to adjust parameter *P* from *W1* to *W2* has infeasibility rank *R*	belief(agent, has_action_option_rank(adjust_to(P: PARAMETER, W1:REAL, W2:REAL), R:REAL)
the agent believes that the feasibility threshold is *FT*	belief(agent, feasiblity_threshold(FT:REAL))
the agent proposes the action to adjust parameter *P* from *W1* to *W2*	action_proposal(agent, adjust_to(P: PARAMETER, W1:REAL, W2:REAL))

Table 4 Formalization of concepts in the support model

The formalization of the dynamic relationships is as follows.

SDR1 Low emotion member identification

If the ambient agent believes that *A* has emotion level *V* at *T0*
and that the low threshold is *LT*
and $V \leq LT$
then the agent will believe that *A* is a low emotion member

```
belief(agent, has_emotion_level_at(A, V, T0)) &
belief(agent, low_threshold(LT)) &
V≤LT
→ belief(agent, low_emotion_member(A))
```

SDR2 High emotion member identification

If the ambient agent believes that *A* has emotion level *V* at *T0*
and that the high threshold is *HT*
and $V \geq HT$
then the agent will believe that *A* is a high emotion member

```
belief(agent, has_emotion_level_at(A, V, T0)) &
belief(agent, high_threshold(HT)) &
V≥HT
→ belief(agent, high_emotion_member(A))
```

SDR3 Heuristic generation of expressiveness action options for low emotion members

If the ambient agent believes that *A* is a low emotion member
and a group emotion deficient *ED* at *T* was identified
and it believes that the adjustment extent is *AE*
and the expressiveness of *A* is *E*
then the agent will believe that an action option is to change the value *E* for expressiveness to *E* - *AE*ED*E*

```
belief(agent, low_emotion_member(A)) &
assessment(agent, group_emotion_deficient_at(ED, T)) &
belief(agent, adjustment_extent(AE)) &
belief(agent, has_expressiveness(A, E))
→ belief(agent, action_option(adjust_to(expressiveness(A), E, E -
AE*ED*E)))
```

SDR4 Heuristic generation of channel action options for low emotion members

If the ambient agent believes that *A* is a low emotion member
and that a group emotion deficient *ED* at *T* was identified
and that the adjustment extent is *AE*
and the channel from *A* to B has strength *C*
then the agent will believe that an action option is to change the value *C* for channel strength to *C* - *AE*ED*C*

```
belief(agent, low_emotion_member(A)) &
assessment(agent, group_emotion_deficient_at(ED, T)) &
belief(agent, adjustment_extent(AE)) &
belief(agent, has_channel_strength(A, B, C))
→ belief(agent, action_option(adjust_to(channel_strength(A, B), C, C
- AE*ED*C)))
```

SDR5 Heuristic generation of openness action options for low emotion members

If the ambient agent believes that *A* is a low emotion member
and a group emotion deficient *ED* at *T* was identified
and it believes that the adjustment extent is *AE*
and the openness of *A* is *D*
then the agent will believe that an action option is to change the value *D* for openness to *D* + *AE*ED*(1-D)*

```
belief(agent, low_emotion_member(A)) &
assessment(agent, group_emotion_deficient_at(ED, T)) &
belief(agent, adjustment_extent(AE)) &
belief(agent, has_openness(A, D))
→ belief(agent, action_option(adjust_to(openness(A), D, D+
AE*ED*(1-D))))
```

SDR6 Heuristic generation of expressiveness action options for high emotion members

If the ambient agent believes that *A* is a high emotion member
and a group emotion deficient *ED* at *T* was identified
and it believes that the adjustment extent is *AE*
and that the expressiveness of *A* is *E*
then the agent will believe that an action option is to change the value *E* for expressiveness to *E + AE*ED*(1-E)*

belief(agent, high_emotion_member(A)) &
assessment(agent, group_emotion_deficient_at(ED, T)) &
belief(agent, adjustment_extent(AE)) &
belief(agent, has_expressiveness(A, E))
→ belief(agent, action_option(adjust_to(expressiveness(A), E, E + AE*ED*(1-E))))

SDR7 Heuristic generation of channel action options for high emotion members

If the ambient agent believes that *A* is a high emotion member
and that a group emotion deficient *ED* at *T* was identified
and that the adjustment extent is *AE*
and that the channel from *A* to B has strength *C*
then the agent will believe that an action option is to change the value *C* for channel strength to *C + AE*D*(1-C)*

belief(agent, high_emotion_member(A)) &
assessment(agent, group_emotion_deficient_at(ED, T)) &
belief(agent, adjustment_extent(AE)) &
belief(agent, has_channel_strength(A, B, C))
→ belief(agent, action_option(adjust_to(channel_strength(A, B), C, C + AE*ED*(1-C))))

SDR8 Heuristic generation of openness action options for high emotion members

If the ambient agent believes that *A* is a high emotion member
and a group emotion deficient *ED* at *T* was identified
and it believes that the adjustment extent is *AE*
and that the openness of *A* is *D*
then the agent will believe that an action option is to change the value *D* for openness to *D - AE*ED*D*

belief(agent, high_emotion_member(A)) &
assessment(agent, group_emotion_deficient_at(ED, T)) &
belief(agent, adjustment_extent(AE)) &
belief(agent, has_openness(A, D))
→ belief(agent, action_option(adjust_to(openness(A), D, D - AE*ED*D)))

SDR9 Ranking action options

If the ambient agent believes that an action option is to change the value *W1* for *P* to *W2*
and it believes that *P* has infeasibility factor *IF*
then the agent will believe that the action option has infeasibility rank *IF*(W2-W1)*

belief(agent, action_option(adjust_to(P, W1, W2)))
belief(agent, has_infeasibility_factor(P, IF))
→ belief(agent, has_action_option_rank(adjust_to(P, W1, W2), IF*(W2-W1)))

SDR10 Generation of action proposals

If the ambient agent believes that the action option has infeasibility rank *R*
and that the feasibility threshold is *FT*
and *R≤FT* and *R≥-FT*
then it will generate the action option as an action proposal.

belief(agent, has_action_option_rank(adjust_to(P, W1, W2), R)) &
belief(agent, feasiblity_threshold(FT)) &
R≤FT & R≥-FT
→ action_proposal(agent, adjust_to(P, W1, W2))

5. Simulation Results

To illustrate the group emotion support model described in previous sections, by a specific example, a specific scenario is addressed. The simulation for the analysis process is discussed in Section 5.1. Section 5.2 shows the simulation for the support mechanisms.

5.1 Simulation of analysis process

In this section the simulation results of the analysis process are shown in an example scenario that represents a situation where the group emotion is happiness and is analyzed by the ambient agent. The LEADSTO software environment [7] has been used to perform a number of simulation experiments. In this example, the ambient agent generates beliefs on the individual emotion levels of three group members, named Arnie, Bernie and Charlie (see ADR2), and of the group emotion level at different points in time (see ADR5). The agent also assesses the (expected) group's emotion deficient at a future time point based on its belief of the group emotion level and the norm for the group emotion level. The norm of the group emotion can be set by the modeler and represents in this example an optimal level of happiness, at which the team can perform as optimal as possible. The norm was set to *0.62* in this example.

In this example scenario, Arnie is very happy (initial emotion level = *0.9*), he can not receive other emotions (because his δ and receiving α's are zero), however, he is able to send emotions (his ε is not zero). Bernie is not happy (initial emotion level is *0.05*), he can not receive emotions (his δ is zero), but he can send emotions (his ε is not zero). The contagion strengths toward Arnie and Bernie are zero. If these strengths stay zero, Arnie and Bernie will stay on the same emotion level. Finally, Charlie is also not happy (initial emotion level = *0.3*), but he can receive and send emotions quite strongly (because his δ is *0.9* and his ε is *1*). For an overview of the settings, see Table 5.

	Arnie	*Bernie*	*Charlie*
Initial emotion level q	*0.9*	*0.05*	*0.3*
expressiveness ε	*0.6*	*0.5*	*1*
outgoing channel strengths α	*0*	*0.6*	*0.6*
openness δ	*0*	*0*	*0.9*
relevance ρ	*0.34*	*0.33*	*0.33*

Table 5 Parameter Settings in Example Scenario

In Figure 1 a simulation trace is shown in which the horizontal axis represents time, and the vertical axis represents quantitative information about generation of ambient agent's beliefs on the individual and group emotion levels at different (future) time points. In this situation the total group emotion level goes from *0.64* to *0.59* in 500 time steps. This means that the group emotion level is above the norm of *0.62* at first, but will get below this norm later. The idea of the analysis model is that our ambient agent predicts this downward development early in time (long before it actually happens), so it can propose appropriate actions to the team leader early in time, to prevent this from happening. The simulations are based on step size Δt = *0.1*.

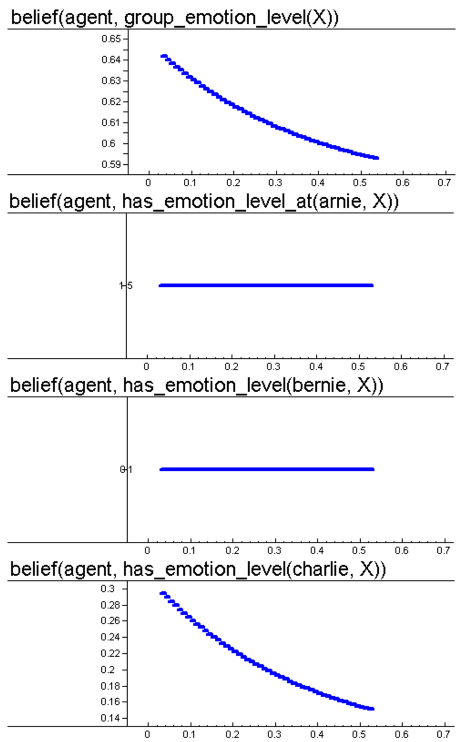

Figure 1 Simulation trace of the analysis processes

In Figure 1, on the x-axis time goes from *0* to *0.7*. This is the processing time of the ambient agent. The idea is that the agent reads the emotions of the persons at time point 0 and from that time point ambient agent starts to generate beliefs on the development of the emotion levels of the group members and the group as a whole. This simulation can be found in all the graphs of the individual and group emotion. The developments of the emotion levels (simulated by the ambient agent from time point *0* to *0.5*) are estimated for the future time points *0* to *5*. Figure 2 shows the assessment of the expected emotion deficient by the ambient agent (see ADR6). Due to space limitation, only that part is shown where assessment is generated. At time point *0.55* on the x-axis the ambient agent makes an assessment of the future group emotion level deficient for time point *5*. The ambient agent assesses that on future time point *5* indeed there is a group emotion deficient to be expected (of about *0.027*).

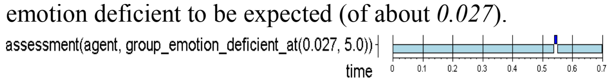

Figure 2 Simulation trace for assessment of emotion deficient

5.2 Simulation of the support process

In this section the example scenario of the previous section is extended with the support of the ambient agent. The assumption is made that Arnie is working separately from Bernie and Charlie; i.e., he works in a different office than Bernie and Charlie. Therefore, Arnie's channels to Bernie and Charlie have strength *0*. Previously, the ambient agent assessed that there is a nonzero emotion deficient expected: the group emotion level slowly gets below the group emotion level norm of *0.62*. Therefore, based on its heuristics, the ambient agent detects which group members are high or low emotion members, and generates action options that decrease or increase parameters related to these members: expressiveness, openness or channel strength. After ranking these options, the agent proposes to the group leader those options, which do not exceed a certain feasibility threshold. An example of (a part of) such a trace is shown in Figure 3. Here, time is on the horizontal axis, and state properties are on the vertical axis. A dark box indicates that a state property is true. Figure 3 shows that the ambient agent detects the high and/or low emotion members (Arnie is detected as a high emotion member and Bernie as a low emotion member.) (see SDR1 and SDR2), the action-options are ranked (see SDR9) and the ambient agent proposes the actions that do not exceed the feasibility threshold to the group leader (see SDR10).

6. Discussion

Complex and critical tasks are often allocated to teams. An important task of in particular a team leader is to maintain a good spirit in the team. As circumstances may be stressful and due to high pressure, task performance may be disappointing from time to time, this is a nontrivial task. Emotions within the team may easily become more and more negative. The team leader has as a special responsibility to regulate such patterns.

The literature on emotion contagion addresses how emotions of group members can affect each other. Based on such literature, in [6] a computational model is presented for emotion contagion based on the idea of mutual absorption of emotions. This emotion contagion model was taken as a point of departure for the work reported in the current paper. An ambient agent model was presented that uses the computational model to analyze the expected group emotion levels at future time points, and to propose actions to the team leader to regulate the group emotion. The approach is modular in that it is easy to replace the emotion contagion model used as a point of departure by a different one.

One of the possible applications of this ambient agent model could be analyzing and supporting group emotion in virtual meetings. For example, when two groups at two locations in the world are video-

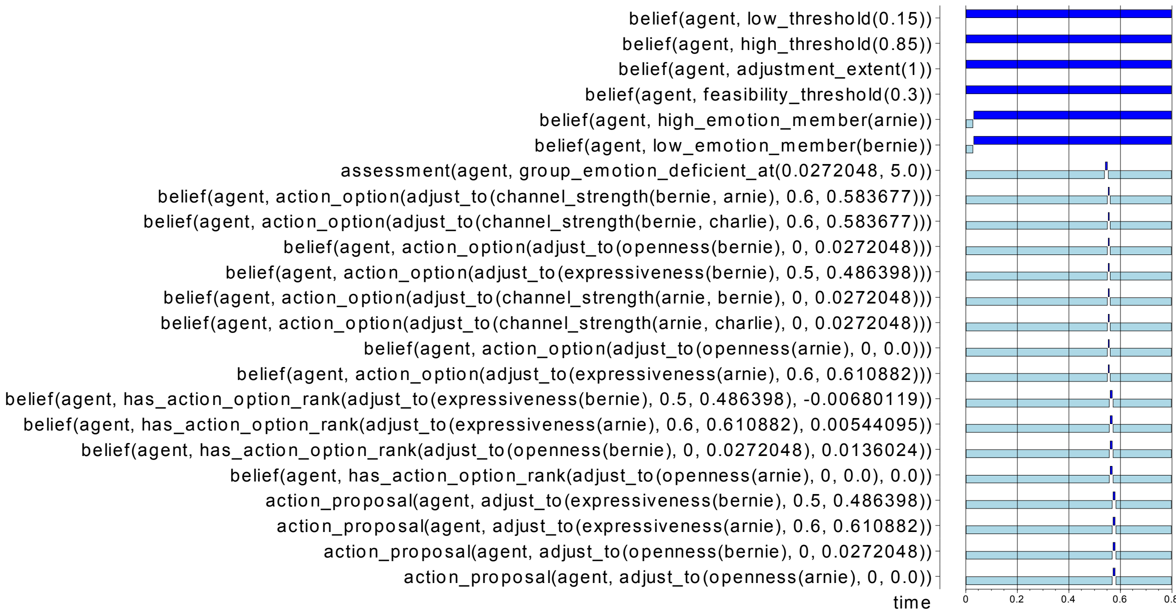

Figure 3 Simulation trace of heuristics and action proposals

conferencing, a software agent could measure the group emotion of both groups and could show the emotion level of the other group to the group leaders. The software agent could then, if necessary, provide support to the group leaders, e.g. when is the best time to let the other group make a decision, or how to calm the other group down after their angry level got too high during decision making.

So far only one emotion at a time is analyzed in the ambient agent model, but this can easily be extended to take into account multiple emotions as long as they are considered as independent from each other. For specific types of emotions specific values may have to be estimated, e.g. α, δ, ρ. However, if also interaction between different emotions is to be addressed (for example, anger in one person affecting fear in another person), more specific work is needed, which is planned for the future. The emotion contagion model used as a point of departure is based on a principle of mutual absorption. This may be applicable well to a certain type of group members. However, also group members may exist who by their personality amplify the emotions observed in others beyond the boundaries of emotion levels that already exist in the group. To cover such more extreme cases a different emotion contagion model is needed, which is also planned to be developed in future work.

7. References

[1] Frijda, Nico H. 2007. *The laws of emotion*. Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

[2] Ortony, A., Clore, G., & Collins, A. *The Cognitive Structure of Emotions*. Cambridge: Cambridge University Press, 1988.

[3] Elliott, Clark. 1992. *The Affective Reasoner: A Process Model of Emotions in a Multi-Agent System* 'The Institute for the Learning Sciences, Technical Report #32, PhD thesis, Northwestern University.

[4] Marsella, Stacy and Gratch Jonathan. EMA: A process model of appraisal dynamics, *Journal of Cognitive Systems Research*, vol. 10, no. 1, pp. 70-90, 2009.

[5] Broekens, Joost., Netten, Niels. and DeGroot, Doug. 2005. Consistent Dynamic-Group Emotions for Virtual Agents. *Proceedings of the 16th Belgium-Netherlands Conference on Artificial Intelligence* University of Groningen.

[6] Bosse, T., Duell, R., Memon, Z.A., Treur, J., and Wal, C.N. van der, A Multi-Agent Model for Mutual Absorption of Emotions. In: Otamendi, J., Bargiela, A., Montes, J.L., Pedrera, L.M.D. (eds.), *Proceedings of the 23rd European Conference on Modelling and Simulation, ECMS'2009*. European Council for Modelling and Simulation, 2009, pp. 212-218.

[7] Bosse, T., Jonker, C.M., Meij, L. van der, and Treur, J. (2007). A Language and Environment for Analysis of Dynamics by Simulation. *International Journal of Artificial Intelligence Tools*, vol. 16, 2007, pp. 435-464.

[8] Barsade, S.G. and Gibson, D.E. (1998). Group Emotion: a View from Top and Bottom. In: D. Gruenfeld, E. Mannix and M. Neale, Editors, *Research on managing groups and teams*, JAI Press, Stamford (1998), pp. 81–102.

[9] McCrae, R.R., & Costa, P.T. (1987) Validation of the five-factor model of personality across instruments and observers. *J. of Personality and Social Psychology, 52, 81-90.*

[10] Gray, J. (1990). Brain systems that mediate both emotion and cognition. *Cognition and Emotion*, 4, 269-288.

[11] Hareli, S., and Rafaeli, A. (2008). Emotion cycles: On the social influence of emotion in organizations. *Research in Organizational Behavior*, 28, pp 35-59.