Designing Social Agents with Empathic Understanding

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Abstract. This paper addresses the design of an agent model for a social agent capable of understanding other agents in an empathic way. The model describes how the empathic agent deals with another agent's mental states and the associated feelings, thus not only understanding the other agent's mental state but at the same time feeling the accompanying emotion of the other agent.

1 Introduction

For functioning within a social context, one of the important issues is in how far agents have a good understanding of one another. Having understanding of another agent often is related to the notion of mindreading or Theory of Mind (ToM). This is a very wide notion, subsuming various foci of the understanding (such as attention, intention, desire, emotion, or belief states) and various methods for it, for example, based on the Theory Theory perspective or the Simulation Theory perspective as known from the philosophical literature; e.g., (Gärdenfors, 2003; Goldman, 2006).

For humans, one of the deepest and most fundamental forms of mutual understanding is based on the notion of empathy; e.g., (Ickes, 1997; Hoffman, 2000; Preston and Waal, 2002; Decety and Jackson, 2004; Lamm, Batson, and Decety, 2007; Iacoboni, 2005, 2008). Originally (cf. Lipps, 1903) the notion of empathy was named by the German word 'einfühlung' which could be translated as 'feeling into'; e.g., (Preston and Waal, 2002). As this word indicates more explicitly, the notion has a strong relation to feeling: empathic understanding is a form of understanding which includes (but is not limited to) feeling what the other person feels. This paper addresses how an agent can be designed that is able to have empathic understanding of other agents.

A particular challenge here is how to relate understanding of any mental state (such as an attention, belief, desire or intention state) of another agent to a form of understanding which includes feeling the same emotion as the other agent. As one of the points of departure for an approach to address this challenge, Damasio (1999, 2004)'s theory was adopted, describing how any internal state or external stimulus provokes an emotion in the form of a bodily response that is felt via sensing this body state: a body loop. As a variant an as if body loop goes via preparations for a body state directly to a

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sensory representation of this body state. As another point of departure the Simulation Theory perspective on mindreading (e.g., Goldman, 2006) was adopted, which assumes that mindreading focussing on certain mental states of an observed agent makes use of the same mental states within the observing agent.

In this paper, first the notion of empathy is clarified and positioned (Section 2) and Damasio's theory on the generation of feelings is briefly introduced (Section 3). In Section 4 the designed agent model for empathic understanding is introduced and in Section 5 some simulation results are discussed. Finally, Section 6 is a discussion.

2 Empathy and Different Types of Mindreading

Empathy can be considered a specific type of mindreading. In the literature, empathy is described in different manners:

- The ability to put oneself into the mental shoes of another person to understand his or her emotions and feelings (Goldman, 1993)
- A complex form of psychological inference in which observation, memory, knowledge, and reasoning are combined to yield insights into the thoughts and feelings of others (Ickes, 1997)
- An affective response more appropriate to someone else's situation than to one's own (Hoffman, 1982)
- An affective response that stems from the apprehension or comprehension of another's emotional state or condition, and which is similar to what the other person is feeling or would be expected to feel in the given situation (Eisenberg, 2000)

Recurring aspects in such descriptions are on the one hand understanding, having insight in, apprehension or comprehension, and on the other hand feeling the state of the other person. Here the state of the other person may involve emotions felt and/or other mental states of the person. For the sake of simplicity, below notions such as understanding, having insight in, apprehension, comprehension, are indicated as understanding. For example, a person may understand but not feel an emotion felt by another person. These distinctions can be used more generally to obtain a form of classification of different types of mindreading that are possible. More specifically, mindreading can address three types of states of an observed person:

(a) Emotions felt by the person
(b) Other mental states (e.g., attention states, desire, intention, belief states)
(c) Both emotion states and other mental states

Moreover, this not only applies to a person who is observed but also to a person performing the observing. In particular, a person can understand or feel another person's state, or both. Given this, mindreading of another person's state can take three forms:

(1) Feeling the state of another person without understanding it
(2) Understanding the state of another person without feeling it
(3) Both understanding and feeling the state of another person

As the other person's state may involve emotions felt and/or other mental states, the combination of these provides the matrix of possibilities as shown in Table 1.

For example, the possibility indicated as type (1a), 'feeling but not understanding another person's emotion', is a case of emotion contagion as often occurs in the interaction between persons (e.g., Hatfield, Cacioppo, and Rapson, 1994). Here the emotion felt by one person is mirrorred in the emotion felt in the other person. Another specific case is type (2c): 'understanding but not feeling another person's emotions and other mental states'. This is a case that is often assumed to occur in psychopaths who have well-developed skills in mindreading and apply them to their victims thereby serving their own interest, but do not mirror the feelings of their victims (cf. Raine, 1993, pp. 159-165; Blair, 2005). Yet other specific cases are type (2b) which subsumes classicical cases described by the Theory Theory perspective on mindreading (e.g., Goldman, 2006; Bosse, Memon, and Treur, 2007), and type (2a) that subsumes approaches based on dedicated emotion recognition methods, for example, from facial expressions; e.g., (Pantic and Rothkrantz, 2000).

Table 1. Different types of mindreading

Observed person ***Observing person***	*Other person's emotions felt* (a)	*Other person's other mental states* (b)	*Other person's emotions felt and other mental states* (c)
Feeling but not understanding (1)	Feeling but not understanding another person's emotion	Feeling but not understanding another person's belief, desire, intention, attention, …	Feeling but not understanding another person's emotions and other mental states
Understanding but not feeling (2)	Understanding but not feeling another person's emotion	Understanding but not feeling another person's belief, desire, intention, attention, …	Understanding but not feeling another person's emotions and other mental states
Both understanding and feeling (3)	Understanding and feeling another person's emotion	Understanding and feeling another person's belief, desire, intention, attention, …	Understanding and feeling another person's emotions and other mental states

Some of the descriptions of the notion of empathy (e.g., in the descriptions from (Goldman, 1993; Hoffman, 1982; Eisenberg, 2000) quoted above) concentrate on feelings and mirrorring them, which could be described as being subsumed by type (1a) or (3a). However, other descriptions explicitly involve thoughts as well, of both the observed and observing person (e.g., Ickes, 1997), which makes them subsumed by type (3c). In the current paper this more extended (and challenging) notion of empathy is taken as the aim. Here an extra aspect is that feelings and other mental states are interrelated: usually any mental state of a person that by itself is not an emotion state (for example, a belief, desire, intention or attention state) induces or goes together with a certain emotion state. For example, a belief that something bad is to happen, may relate to feeling fear, or the belief that something good has happened may relate to feeling happiness. Another example of such a relationship is the role of cognitive elements (for example, certain thoughts) in the development, persistence and recurrence of mood disorders such as depressions; e.g., (Ingram, Miranda & Segal, 1998).

3 Relating Mental States to Emotions Felt

A question that may arise from the distinctions made in the previous section is whether it is possible to feel a state of another person which by itself is not a feeling, for example, a belief state. An answer to this involves the way in which any mental state in a person induces emotions felt within this person, as described by Damasio (1999, 2004); e.g.:

> 'Even when we somewhat misuse the notion of feeling – as in "I feel I am right about this" or "I feel I cannot agree with you" – we are referring, at least vaguely, to the feeling that accompanies the idea of believing a certain fact or endorsing a certain view. This is because believing and endorsing *cause* a certain emotion to happen. As far as I can fathom, few if any exceptions of any object or event, actually present or recalled from memory, are ever neutral in emotional terms. Through either innate design or by learning, we react to most, perhaps all, objects with emotions, however weak, and subsequent feelings, however feeble.' (Damasio, 2004, p. 93)

From this perspective, if any mental state of an observed person is mirrorred within an observing person, by an (assumingly) similar mechanism the associated feeling can also be generated within the observing person. In principle, this can even happen for the case where the observed person has a damaged neural structure causing that this associated feeling is not generated. In this case the observing person can feel the other person's state, whereas the person himself does not feel it. For example, if such a person believes he has won a lottery, he may not feel happiness about it, whereas an observing agent may mirror such a belief and based on that may generate the accompanying feeling of happiness.

In some more detail, emotion generation via a body loop roughly proceeds according to the following causal chain; see Damasio (1999, 2004):

having a mental state → preparation for the induced bodily response → induced bodily response → sensing the induced bodily response → sensory representation of the induced bodily response → induced feeling

As a variation, an 'as if body loop' uses a direct causal relation

preparation for the induced bodily response →
sensory representation of the induced bodily response

as a shortcut in the causal chain. In the model used here an essential addition is that the body loop (or as if body loop) is extended to a recursive body loop (or recursive as if body loop) by assuming that the preparation of the bodily response is also affected by the state of feeling the emotion:

feeling → preparation for the bodily response

as an additional causal relation. Such recursiveness is also assumed by Damasio (2004), as he notices that what is felt by sensing is actually a body state which is an internal object, under control of the person:

'The brain has a direct means to respond to the object as feelings unfold because the object at the origin is inside the body, rather than external to it. The brain can act directly on the very object it is perceiving. It can do so by modifying the state of the object, or by altering the transmission of signals from it. The object at the origin on the one hand, and the brain map of that object on the other, can influence each other in a sort of reverberative process that is not to be found, for example, in the perception of an external object.' (…)

'In other words, feelings are not a passive perception or a flash in time, especially not in the case of feelings of joy and sorrow. For a while after an occasion of such feelings begins – for seconds or for minutes – there is a dynamic engagement of the body, almost certainly in a repeated fashion, and a subsequent dynamic variation of the perception. We perceive a series of transitions. We sense an interplay, a give and take.' (Damasio, 2004, pp. 91-92)

Thus the obtained model is based on reciprocal causation relations between emotion felt and body states, as roughly shown in Figure 1.

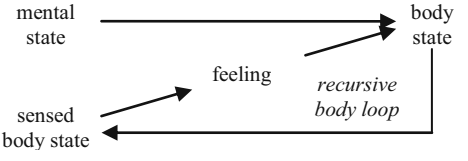

Fig. 1. Recursive body loop induced by a given mental state

Both the bodily response and the feeling are assigned a level or gradation, expressed by a number, which is assumed dynamic; for example, the strength of a smile and the extent of happiness. The causal cycle is modelled as a positive feedback loop, triggered by the (any) mental state and converging to a certain level of feeling and body state. Here in each round of the cycle the next body state has a level that is affected by both the mental state and the level of the feeling state, and the next level of the feeling is based on the level of the body state.

4 Description of the Designed Agent Model

The design of the mindreading capability for the empathic agent was based on the Simulation Theory perspective; cf. (Goldman, 2006). According to this perspective mindreading is performed by the observing agent by activating the same own mental states as the observed agent, thereby using similar mechanisms as those used by the observed agent. Therefore, a first step is the design of the basic mechanisms to generate a mental state (here en belief state was chosen), and to generate the associated feelings. These basic mechanisms will be used by both agents.

In the description of the detailed agent model 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 details see (Bosse, Jonker, Meij & Treur, 2007).

A lottery scenario is used to illustrate the model. Agent A observes both his own lot number and the winning number and creates the corresponding beliefs; as the number in both beliefs is the same, from these the belief that the lottery was won is generated, which leads to an associated feeling of happiness. By communication agent B hears from agent A about the own lot number and the winning number. From this he simulates the process in agent A thus entering an empathic understanding process in which she generates both the belief about the lottery won and the associated feeling. For an overview of the model for agent A, see Figure 2. An overview of the model of agent B is depicted in Figure 3. These pictures also show representations from the detailed specifications explained below.

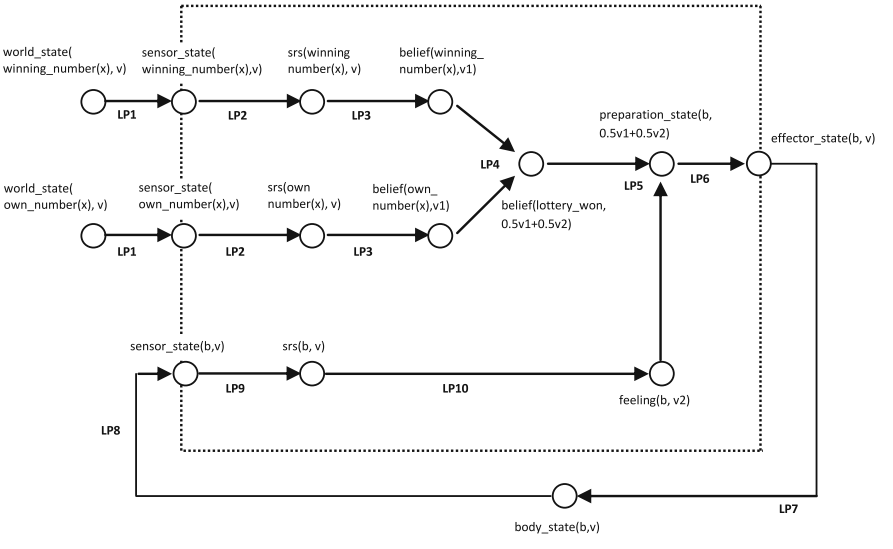

Fig. 2. Overview of the agent model for the observed agent A

The detailed specification (both informally and formally) of the agent model for empathic understanding is presented below. Here capitals are used for (assumed universally quantified) variables, e.g. 'B', whereas small letters represents an instance of that variable, e.g. 'b'. All aspects have been formalized numerically by numbers in the interval [0, 1]. First the part is presented that describes the basic mechanisms to generate a belief state (on winning the lottery) and the associated feeling (of happiness). These are used by both agents. The first dynamic property addresses how properties of the world state can be sensed.

LP1 Sensing a world state
If world state property *W* occurs of level *V*
then a sensor state for *W* of level *V* will occur.
world_state(W, V) → sensor_state(W, V)

This dynamic property is used by agent A to observe both the own number and the winning number (see Figure 2); to this end the variable W is instantiated by own_number(x) and winning_number(x). Note that communications are also considered world facts; LP1 is used by agent B by instantiating W for communications indicated as communicated_by_to(I, agentA, agentB). From this sensory representations and beliefs are generated according to the next two dynamic properties LP2 and LP3. Note that also for these the variable W is instantiated as before.

LP2 Generating a sensory representation for a sensed world state
If a sensor state for world state property *W* with level *V* occurs,
then a sensory representation for *W* with level *V* will occur.
sensor_state(W, V) → srs(W, V)

LP3 Generating a belief state for a sensory representation
If a sensory representation for *W* with level *V* occurs,
then a belief for *W* with level *V* will occur.
srs(W, V) → belief(W, V)

Dynamic property LP4 describes how the belief is generated that the lottery was won.

LP4 Generating a belief on winning the lottery
If a belief with level *V1* occurs that *X* is the main price winning number of the lottery
and a belief with level *V2* occurs that *X* is the number of the own lot
then a belief with level *0.5V1+0.5V2* will occur that the main price of the lottery was won
belief(winning_number(X), V1) & belief(own_number(X), V2) →
belief(lottery_won, 0.5V1+0.5V2)

The emotional response to this belief is the preparation for a specific bodily reaction b, as expressed in dynamic property LP5.

LP5 From belief that lottery was won and feeling to preparation of a specific body state
If a belief that the lottery was won with level *V1* occurs and feeling body state b has level *V2*,
then preparation state for body state *b* will occur with level *0.5V1+0.5V2*.
belief(lottery_won, V1) & feeling(b, V2) → preparation_state(b, 0.5V1+0.5V2)

Dynamic properties LP6 to LP10 describe the body loop.

LP6 From preparation to effector state for body modification
If preparation state for body state *B* occurs with level *V*,
then the effector state for body state *B* with level *V* will occur.
preparation_state(B, V) → effector_state(B, V)

LP7 From effector state to modified body
If the effector state for body state *B* with level *V* occurs,
then the body state *B* with level *V* will occur.
effector_state(B, V) → body_state(B, V)

LP8 Sensing a body state
If body state *B* with level *V* occurs,
then this body state *B* with level *V* will be sensed.
body_state(B, V) → sensor_state(B, V)

LP9 Generating a sensory representation of a body state
If body state *B* with level *V* is sensed,
then a sensory representation for body state *B* with level *V* will occur.
sensor_state(B, V) → srs(B, V)

LP10 From sensory representation of body state to feeling
If a sensory representation for body state *B* with level *V* occurs,
then *B* is felt with level *V*.
srs(B, V) → feeling(B, V)

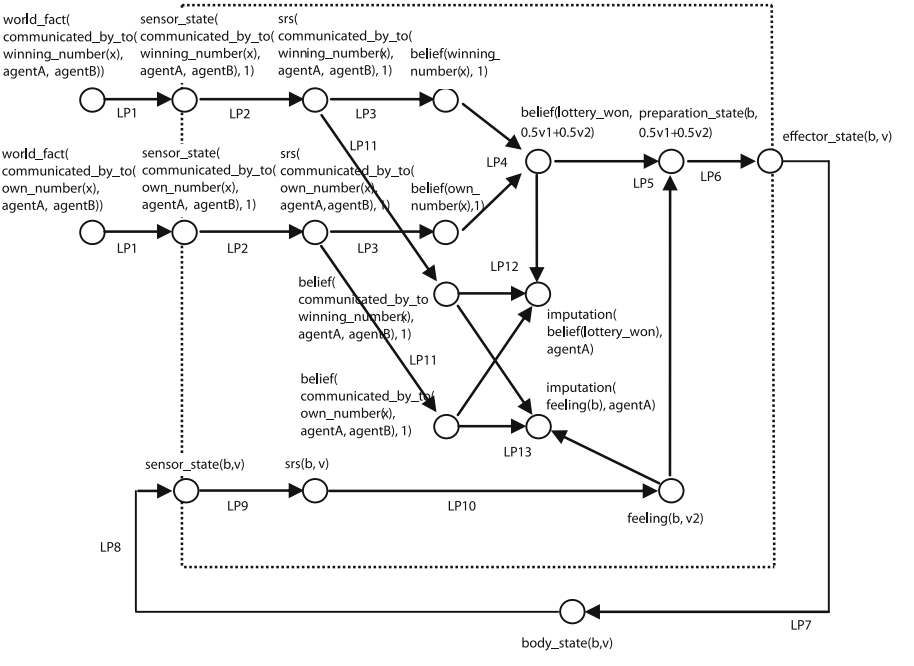

Fig. 3. Overview of the agent model for the observing agent B

Above the part of the model was shown that is used by both the observed and observing agent. Next the part of the model is discussed that is particularly involved in the empathic understanding process. This part of the model is used within the observing agent; see Figure 3.

First the communication from the other agent is related to the own beliefs.

LP11 Affecting own beliefs by communicated information
If in agent B a sensory representation with level *V* occurs that agent A communicated world fact *W*,
then a belief with level *V* for this world fact will occur.
srs(communicated_by_to (W, agentA, agentB), V) → belief(W, V)

Next it is shown how the imputation process takes place for a belief. Here, *th* is a (constant) threshold for imputation. In the simulations shown, th is assumed 0.95 as an example.

LP12 Imputation of a belief
If a belief that the lottery was won with level *V1*≥ *th* occurs
and a belief occurs with level *V2*≥*th* that the own number was communicated by agentA,
and a belief occurs with level *V3*≥*th* that the winning number was communicated by agentA,
then the belief that the lottery was won will imputed.

belief(lottery_won, V1) &
belief(communicated_by_to(own_number(X1), agentA, agentB), V2) &
belief(communicated_by_to(winning_number(X2), agentA, agentB), V3) &
V1≥th & V2≥th & V3≥th
→ imputation(belief(lottery_won), agentA)

Finally, feelings are imputed in the following manner.

LP13 Imputation of a feeling
If a certain body state *B* is felt, with level *V1*≥ *th*
and a belief occurs with level *V2*≥*th* that the own number was communicated by agentA,
and a belief occurs with level *V3*≥*th* that the winning number was communicated by agentA,
then feeling *B* will imputed.

feeling(B, V1) &
belief(communicated_by_to(own_number(X1), agentA, agentB), V2) &
belief(communicated_by_to(winning_number(X2), agentA, agentB), V3) &
V1≥th & V2≥th & V3≥th
→ imputation(feeling(B), agentA)

5 Example Simulation Results

Based on the model described in the previous section, a number of simulations have been performed. Some example simulation traces are included in this section as an illustration; see Figure 4 and Figure 5 (here the time delays within the temporal LEADSTO relations were taken 1 time unit). In all of these figures, where time is on the horizontal axis, the upper part shows the time periods, in which the binary logical state properties hold (indicated by the dark lines); for example,

world_state(winning_number(X), 1)
belief(lottery_won, 1.0)
imputation(feeling(b), agentA)

Below this part, quantitative information for the other state properties values for the different time periods are shown (by the dark lines). For example, in Figure 4, the preparation state for b has value 0.5 at time point 6 which increased to 0.75 at time point 12 and so forth. The graphs show how the recursive body loop approximates a state for feeling with value 1. Notice that in all lower 6 traces i.e. from preparation state to feeling state, the states are activated based on temporal delay between them, as depicted in Figure 2, i.e. preparation state has activation level '0' at time point 0, the successor state effector state has activation level '0' at time point 1 and so on.

Figure 4 shows the simulation for the observed agent based on the basic mechanisms to generate a belief state and to generate the associated feeling as described in

the previous section (from LP1 to LP10). As shown in Figure 4 (upper part), the observed agent A notices his own number and the winning number from the world state, shown by the state properties

sensor_state(own_number(X), 1)

and

sensor_state(winning_number(X), 1)

respectively. It then generates the belief that he has won the lottery by comparing the two numbers shown by the state property

belief(lottery_won(X), 1.0)

The lower part of Figure 4 shows the values of the various activation levels over time. Here it is shown that the recursive body loop results in an approximation of convergent activation levels for the states that relate to the feeling and the body state, among others.

Figure 5 shows a simulation trace for the observing agent, depicting the empathic understanding process described in the previous section (in particular using LP11 to LP13, but also using LP1 to LP10 for the underlying basic mechanism). Here it is shown (in the upper part of the Figure 5) that agent A (observed agent) communicates his own number and winning number to the agent B (observing agent), shown by the state properties

sensor_state(communicated_by_to
(own_number(X), agentA, agentB), 1)

and

sensor_state(communicated_by_to
(winning_number(X), agentA, agentB), 1)

respectively. Stepping in the shoes of agent A, then agent B (the observing agent) generates its own beliefs about the lot numbers and about winning lottery belief (which mirror the beliefs of agent A), as shown by the state property

belief(lottery_won, 1.0).

Later agent B imputes this belief (at time point 5) to agent A as shown by state property

imputation(belief(lottery_won), agentA).

As shown in the figure, after generating the associated feeling, agent B also imputes this feeling to agent A, shown by the state property

imputation(feeling(b), agentA)

at time point 35.

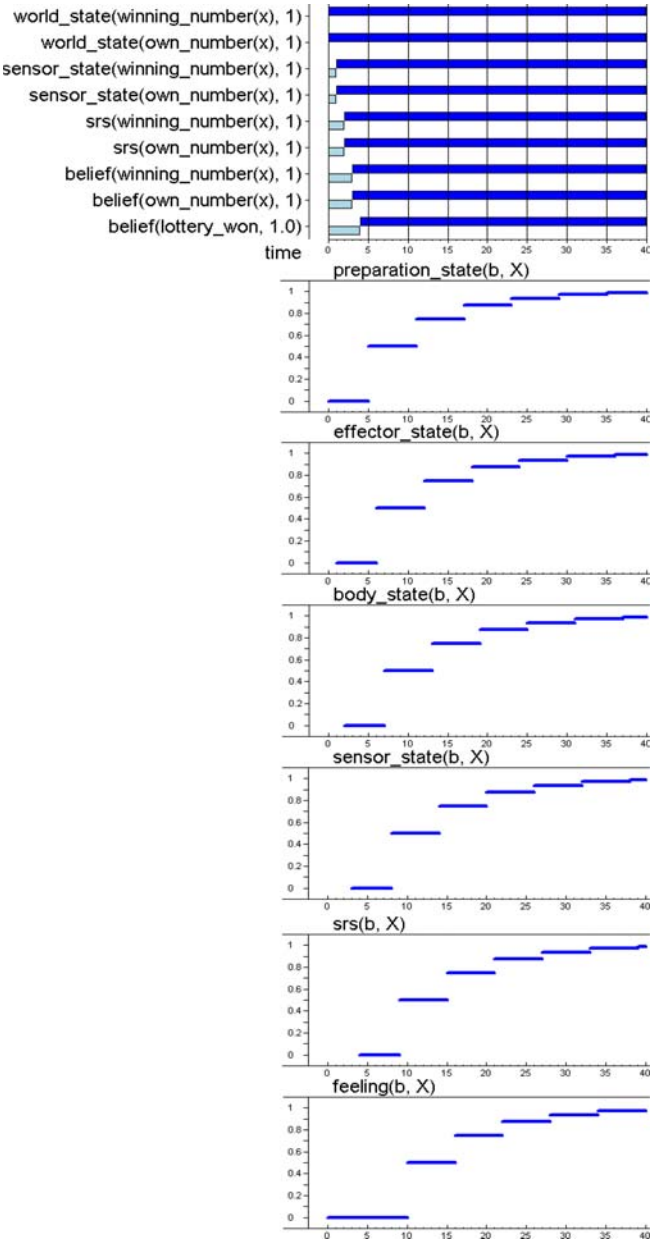

Fig. 4. Example simulation trace for the observed agent

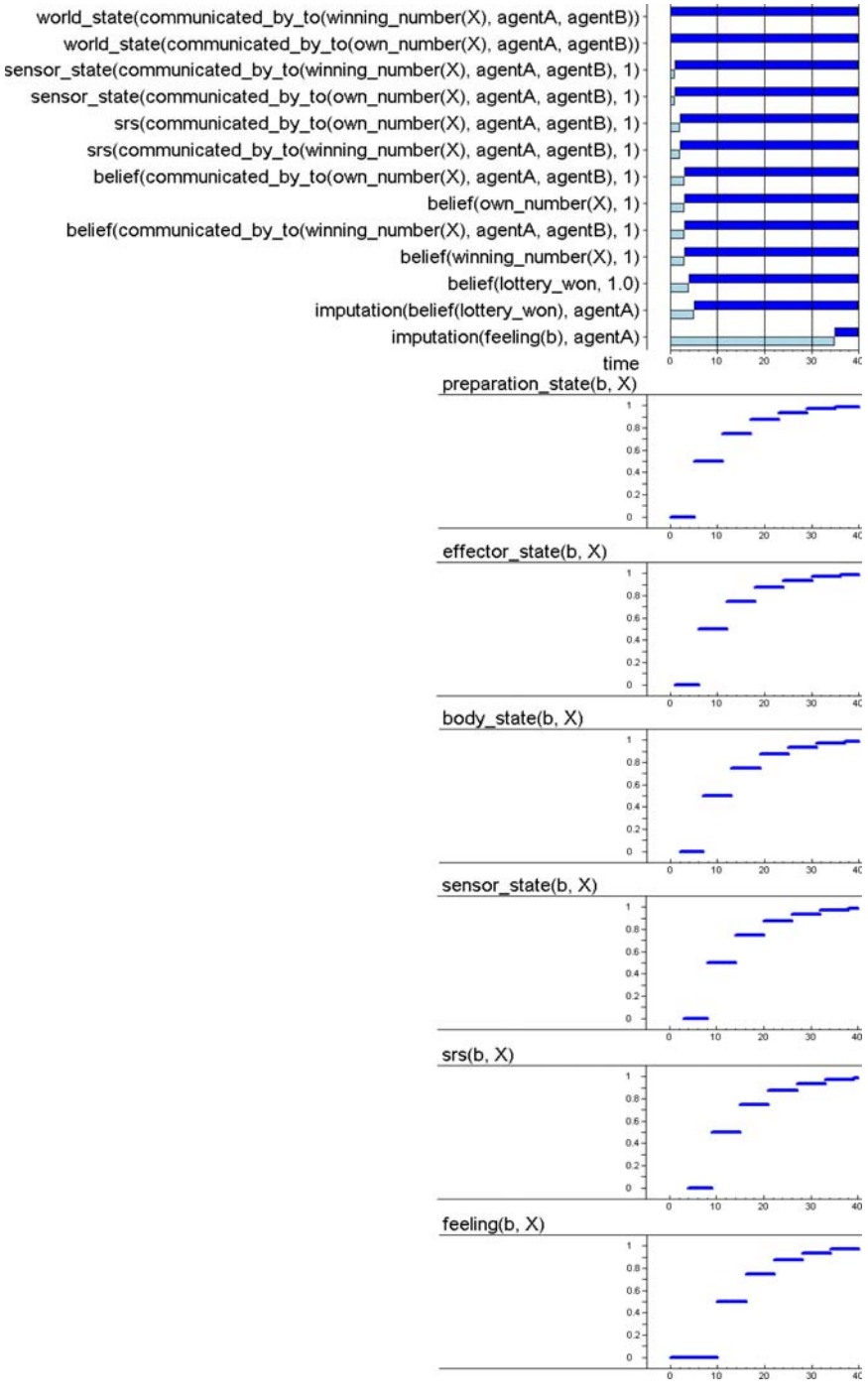

Fig. 5. Example simulation trace for the observing agent

6 Discussion

For an agent observing another agent, having an empathic understanding of the observed agent is considered a specific type of mindreading. Mindreading as such can focus on certain aspects such as emotion, desire, belief, intention, or attention states (e.g., Gärdenfors, 2003). A characteristic of an empathic response is that the response does not only include that the observing agent understands the mental state of the observed agent, but also feels the corresponding feeling. In this paper the design of an agent model was introduced that is capable of understanding other agents in an empathic way. The model describes how the empathic agent does not only understand another agent's mental state but at the same time feels the accompanying emotion. The proposed model is an extension of an earlier model described in (Bosse, Memon, and Treur, 2009) which does not focus on the more complex issue of empathic understanding, but only on reading another person's emotions. The model proposed in the current paper was based on two main assumptions:

(1) The observing agent performs mindreading using the same mental states as the observed agent
(2) Both agents have a similar mechanism to associate feelings to a given mental state

Concerning assumption (1), to obtain a form of mindreading for which the observing agent generates the same mental state, the Simulation Theory perspective was followed; cf. (Goldman, 2006). According to this perspective mindreading is performed by the observing agent in a simulative manner by activating the same mental states as the observed agent; see also (Hesslow, 2002). This assumption is recently getting more and more support by empirical results, for example, concerning the discovery of the mirror neuron system; e.g., (Rizzolatti and Craighero, 2004; Iacoboni, Molnar-Szakacs, Gallese, Buccino, Mazziotta, and Rizzolatti, 2005; Iacoboni, 2005, 2008; Pineda, 2009; Goldman, 2009).

Concerning assumption (2), to this end a computational model of Damasio (1999, 2004)'s informal theory about the generation of emotion and feeling was exploited. This theory assumes a neural mechanism that involves changes in an agent's sensed body state, triggered by a certain mental state. Assuming that the observed agent and the observing agent indeed have a similar mechanism for this, makes it possible that for a given mental state the observing agent generates the same feeling as the observed agent.

Especially in relation to assumption (2) it can be questioned to which extent the mechanisms to associate feelings to a given mental state are the same for both agents. As it may be considered plausible that basically the mechanisms are similar, it is not difficult to imagine that due to innate and learned individual differences, the empathic reaction may be limited in extent. Indeed, it is often reported that identical twins have a much higher level of mutual empathy than any two persons which are not identical twins. Moreover, it is also often considered that more empathy is shown between two persons when they have had similar experiences in life. Nevertheless, a certain extent of empathy still seems possible between persons which are not genetically identical and have not exactly the same experiences. It is an interesting challenge for future research to develop the introduced model for empathy further by introducing explicit

parameters by which such individual differences can be expressed, and for which some notion of extent to which empathy occurs can be defined.

Other models described in the literature usually only address either emotion recognition, or recognition of another type of mental state, or feel another persons feeling; e.g., (Pantic and Rothkrantz, 2000; Goldman, 2006; Bosse, Memon, and Treur, 2007; Hatfield, Cacioppo, and Rapson, 1994). As far as the authors know the model proposed here is unique in the sense that it combines both understanding and feeling of another person's mental states, and takes into account the way in which (other) mental states induce feelings both for the observing and the observed person.

Future work will address a more extensive evaluation and assessment of the model and thereby will explore more variations, for example, of different scenarios with different extents of similarity between the persons, and different values of its parameters such as the threshold value and the weight factors, for example in the generation of the preparation and the belief which were now taken *0.95* and *0.5* respectively.

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