Computational Modeling and Analysis of Therapeutical Interventions for Depression

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Abstract. Depressions impose a huge burden on both the patient suffering from a depression as well as society in general. In order to make interventions for a depressed patient during a therapy more personalized and effective, a supporting personal software agent can be useful. Such an agent should then have a good idea of the current state of the person. A computational model for human mood regulation and depression has been developed in previous work, but in order for the agent to give optimal support during an intervention, it should also have knowledge on the precise functioning of the intervention in relation with the mood regulation and depression. This paper therefore presents computational models for these interventions for different types of therapy. Simulation results are presented showing that the mood regulation and depression indeed follow the expected patterns when applying these therapies. The intervention models have been evaluated for a variety of patient types by simulation experiments and formal verification.

1 Introduction

Major depression is currently the fourth disorder worldwide in terms of disease burden, and is expected to be the disorder with the highest disease burden in high-income countries by the year 2030 (cf. [14]). Effective interventions for treating depressions are of utmost importance for both the patients suffering from a depression as well as for society in general. Supporting software agents can be very helpful in effectively treating a depression by providing personalized support for patients. Thereby, the agent can for example provide feedback on the current situation, give tips, and give certain tasks or assignments. In order for such a personal assistant agents to function effectively, it requires a detailed computational model on the relevant human states and their interrelationship regarding regulation of mood and depression. Such a model can also help to understand and analyze the basics behind a depression better. In [5] an example was shown of a computational model for mood regulation and depression based on literature on emotion and mood regulation. This model however does not explicitly address the functioning of interventions, such as activity scheduling [13] and cognitive restructuring [3]. Particularly for the domain of a personal assistant agent that supports patients during a major depression, knowledge

about the functioning of these therapies is crucial to give effective support. In [6] a first attempt has been made to create such a model that combines the concepts of mood, depression, and a single type of intervention, namely activity scheduling.

This paper presents a computational model of the effect on interventions on mood regulation and depression for a number of frequently used interventions such as activity scheduling, cognitive behavioral therapy, and other types of interventions aiming at enhancing coping skills. Within the model, the main principles of the interventions from psychological literature have been incorporated. This computational model is an extension of the mood regulation and depression model as presented in [5]. The model was used to simulate various patient types and the correctness of the behavior was analyzed using formal verification. The obtained model is suitable to be integrated within a personal assistant agent in order to provide effective support for the patient.

In recent literature many contributions can be found about relations between mood regulation or depression and brain functioning; e.g., [1, 2, 7, 8, 9, 10, 11, 12, 15]. Much neurological support has been found for the processes of emotion and mood regulation, and in particular for modulation (down-regulation) of a negative mood in order to avoid or recover from a depression; e.g., [1, 2, 7, 12]. To capture this process of down-regulation of negative moods has been a basic point of departure for the model designed. More specifically, the model presented in this paper addresses how this down-regulation process can be stimulated and improved by therapeutical interventions.

This paper is organized as follows. In Section 2 the model for mood regulation and depression as taken from [5] is explained in more detail. The various interventions are integrated into the model in Section 3. Section 4 presents simulation results, whereas Section 5 verifies that these results indeed comply with existing theories within clinical psychology. Finally, Section 6 is a discussion.

2 A Model for Mood Regulation and Depression

In order to model mood regulation and depression an existing model has been adopted which is based on psychological and neurological literature on mood regulation (cf. [5]). In this section, this model is explained in more detail. The model as described already incorporates the main influences of interventions upon the states in the model (as an extension to the existing model of [5]). The learning effects for each of the specific therapies will be described in Section 3. Figure 1 shows an overview of the relevant states within the model and the relations between the states. In the figure, the states that are depicted in grey represent states that have been added to model the points of impact of interventions. The same holds for the dashed lines.

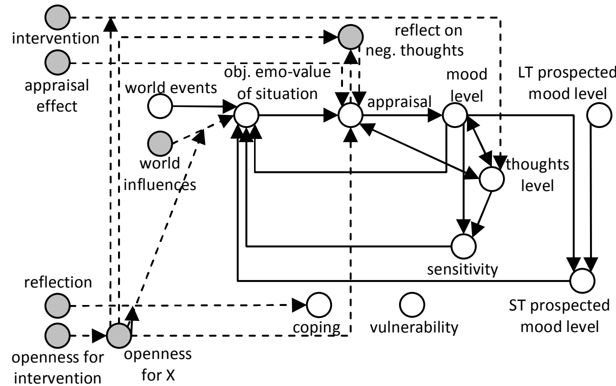

Fig.1. Model for mood and depression
(dashed lines and gray states indicate the extensions compared to [5])

States. In the model, a number of states are defined, whereby each state is represented by a number on the interval [*0,1*]. First, the states of the previous model will be explained. Hereby, the state *objective emotional value of situation* is present, which represents the value of the situation a human is in (without any influence of the current state of mind of the human). The state *appraisal* represents the current judgment of the situation given the current state of mind (e.g. when you are feeling down, a pleasant situation might no longer be considered pleasant). The *mood level* represents the current mood of the human, whereas *thoughts level* the current level of thoughts (i.e. the positivism of the thoughts). The *long term prospected mood level* expresses what mood level the human is striving for in the long term, whereas the *short term prospected mood level* represents the goal for mood on the shorter term (in case you are feeling very bad, your short term goal will not be to feel excellent immediately, but to feel somewhat better). The *sensitivity* indicates the ability to select situations in order to bring the *mood level* to the *short term prospected mood level*. *Coping* expresses the ability of a human to deal with negative moods and situations, whereas *vulnerability* expresses how vulnerable the human is for getting depressed. Finally, *world event* indicates an external situation which is imposed on the human (e.g., losing your job). In addition to the states mentioned above, a number of states have been added to the model. First, a state representing the intervention (i.e., *intervention*) expressing that an intervention is taking place. The state *reflection on negative thoughts* expresses the therapeutic effect that the human is made aware of negative thinking about situations whereas the *appraisal effect* models the immediate effect on the appraisal of the situation. The *world influences* state is used to represent the impact of a therapy aiming to improve the *objective emotional value of situation*. The *openness for intervention* is a state indicating how open the human is for therapy in general, which is made more specific for each specific influence of the therapy in the state *openness for X*. Finally, *reflection* represents the ability to reflect on the relationships between various states, and as a result learn something for the future.

Dynamics. The states as explained above are causally related, as indicated by the arrows in Figure 1. These influences have been mathematically modeled. The first

state to be discussed is the *objective emotional value of situation (oevs)*. This represents the situation selection mechanism of the human. First, the change in situation as would be selected by the human is determined (referred to as *action* in this case) as an intermediate step:

$$action(t) = oevs(t) + sensitivity(t)\,(Neg(oevs(t)\cdot(st_prosp_mood(t)-mood(t)) + Pos((1-oevs(t))\cdot(st_prosp_mood(t)-mood(t))))$$

In the equation, the *Neg(X)* evaluates to *0* in case *X* is positive, and *X* in case *X* is negative, and *Pos(X)* evaluates to *X* in case *X* is positive, and *0* in case *X* is negative. The formula expresses that the selected situation is more negative compared to the previous *oevs* in case the *short term prospected mood* is lower than the current mood and more positive in the opposite case. Note that the whole result is multiplied with the *sensitivity*. The *action* in combination with the external influences now determines the new value for *oevs*:

$$oevs(t+\Delta t) = oevs(t) + (world_event(t)\cdot(action(t) + openness(t)\cdot world_influence(t)\cdot(1 - action(t))) - oevs(t))\cdot\Delta t$$

The above equations basically take the value of actions as derived before in combination with the external influences (i.e. *world influence* and *world event*). The second step is that the human starts to judge the situation (i.e. *appraisal*) based upon his/her own state of mind:

$$appraisal(t+\Delta t) = appraisal(t) + \alpha\,(\gamma + openness_intervention(t)\cdot reflect_neg_th(t) - appraisal(t))\,\Delta t$$

where

$$\gamma = (vulnerability\cdot oevs(t)\cdot thoughts(t) + coping\cdot(1 - (1-oevs(t))\cdot(1-thoughts(t))))$$

The value of *appraisal* is determined by the *thoughts* of the human in combination with the *coping* skills and *vulnerability*. In addition, the intervention related state *reflection on negative thoughts* plays a role (i.e. being aware that you are judging the situation as more negative than a person without a depression) in combination with the openness to this type of intervention. The state *reflection on negative thoughts* is calculated as follows:

$$reflect_neg_th(t) = (basic_reflection(t) + appraisal_effect(t)\cdot openness_X(t))\cdot(1-appraisal(t))$$

Hence, the value increases based upon the *appraisal effect* of the intervention in combination with the *openness* to this specific part of the intervention. Furthermore, a *basic reflection* is expressed, which is the reflection already present in the beginning. Therapy can also dynamically change this *basic reflection* which can be seen as one of the permanent effects of therapy:

$$basic_reflection(t+\Delta t) = basic_reflection(t) + \alpha\; intervention(t)\cdot learning_factor\cdot(1-asic_reflection(t))\Delta t$$

The value for *mood* depends on a combination of the current *appraisal* with the *thoughts*, whereby a positive influence (i.e. *thoughts* and *appraisal* are higher than *mood*) is determined by the *coping* and the negative influence by the *vulnerability*.

$$mood(t+\Delta t) = mood(t) + \alpha\,(Pos(coping\cdot(\varepsilon - mood(t))) - Neg(vulnerability\cdot(\varepsilon - mood(t))))\,\Delta t$$

where

$$\varepsilon = appraisal(t)\cdot w_{appraisal_mood} + thoughts(t)\cdot w_{thoughts_mood}$$

Thoughts is a bit more complex, and is expressed as follows:

$$thoughts(t+\Delta t) = thoughts(t) + \alpha\ (\zeta + (1 - (thoughts(t) + \zeta)) \cdot intervention(t) \cdot w_{intervention}(t))\Delta t$$

where:

$$\zeta = Pos(coping \cdot (appraisal(t) \cdot w_{appraisal_thoughts} + mood(t) \cdot w_{mood_thoughts} - thoughts(t))) - Neg(vulnerability \cdot (appraisal(t) \cdot w_{appraisal_thoughts} + mood(t) \cdot w_{mood_thoughts} - thoughts(t)))$$

$$w_{intervention}(t+\Delta t) = w_{intervention}(t) + \alpha\ (openness_X(t) - w_{intervention}(t))\Delta t$$

This indicates that *thoughts* are positively influenced by the fact that you participate in an intervention (you start thinking a bit more positive about the situation, you are in therapy). The weight of this contribution depends on the *openness* for the intervention at that time point. In addition, the *thoughts* can either be positively influenced due to the higher combination of the levels of *mood* and *appraisal* (again multiplied with the *coping*), or negatively influenced by the same state (whereby the *vulnerability* plays a role). The *sensitivity* is calculated in a similar manner (without the influence of therapy of course):

$$sensitivity(t+\Delta t) = sensitivity(t) + \alpha\ (Pos(coping \cdot (\eta - sensitivity(t))) - Neg(vulnerability \cdot (\eta - sensitivity(t))))\Delta t$$

where

$$\eta = mood(t) \cdot w_{mood_sens} + thoughts(t) \cdot w_{thoughts_sens}$$

Finally, the *short term prospected mood* is calculated as follows:

$$st_prospmood(t+\Delta t) = st_prospmood(t) + \alpha\ (vulnerability \cdot (mood(t) - lt_prospmood) + coping \cdot (lt_prospmood - st_prospmood(t)))\Delta t$$

3 Modeling Interventions for Mood Regulation and Depression

In this section it is shown how the influences of three types of therapies are modeled in the extended model presented in Section 2. First, activity scheduling (cf. [13]) will be discussed, followed by cognitive behavior therapy (cf. [3]). The third model shows how an intervention that addresses coping skills and vulnerability directly can work.

3.1 Activity Scheduling Therapy

Activity scheduling, also called behavioral activation therapy, works according to two principles: the patient learns the relationship between the selection of a relatively positive activity and the level of mood (i.e., when you do fun things, you will start to feel better). In order to learn this relationship again, the therapy imposes the selection of positive situations. In Figure 2 the main influences of this therapy are shown by means of the black arrows. Note that most of the influences have already been explained in the general overview in Section 2. One element part of the therapy states that learning the relationship between *mood* and *objective emotional value of situation* results in better *coping* (as the human can now better cope with a lower mood since he/she knows that an option is to select better situations). This is expressed as follows:

$$coping(t+\Delta t) = coping(t) + \alpha\ reflection(t) \cdot w_{reflection}(t) \cdot (1 - |oevs(t) - mood(t)|\ ) \cdot (1 - coping(t))\ \Delta t$$

where

$$w_{reflection}(t+\Delta t) = w_{reflection}(t) + \alpha\,(openness_as(t) - w_{reflection}(t))\,\Delta t$$

This states that the *coping* will increase as the difference between the *mood* and *oevs* is perceived small (which makes it easy to see the relationship and improve *coping*). Furthermore, an effect is that the openness for the specific therapy increases as the coping skills go up (since the human notices that the therapy works):

$$openness_as(t+\Delta t) = openness_as(t) + \vartheta\,\alpha \cdot((coping(t) - coping(t\text{-}\Delta t))/dt)\,\Delta t$$

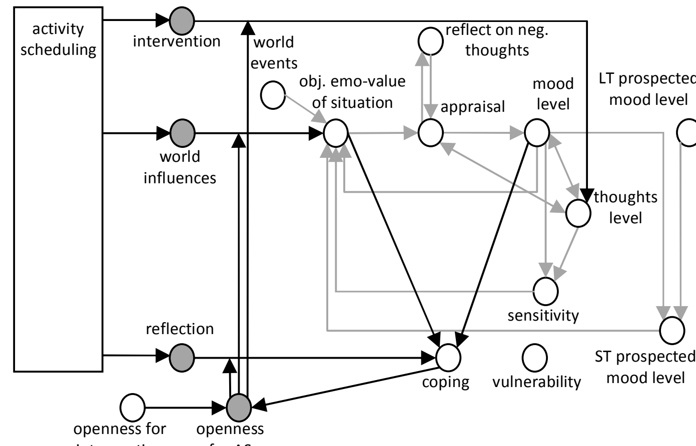

Fig.2. Computational model for activity scheduling therapy

3.2 Cognitive Behavioral Therapy

Most negative situations occur without being able to control them. It is impossible to avoid all bad situations, it is therefore wise to be able to deal with bad circumstances.

The theory behind CBT assumes that emotions are determined by thoughts about a situation and not by the situation itself. In the mood regulation model, it is not the concept 'thoughts level' but the concept 'appraisal' that corresponds to thoughts in the CBT theory, because the thoughts in CBT are about a specific situation, as the state 'appraisal' in the mood regulation model, and do not represent thoughts in general. The intervention CBT consists of understanding (reflection) that thoughts about a situation determine your mood and by detecting and transforming negative thoughts into positive thinking. The fact that you are doing something about your depression improves the *thoughts* level, which is a shared effect of CBT with the other therapies. Figure 3 shows the relevant part of the model for CBT by means of the black arrows. In this case, the reflection is modeled by learning the relationship between *appraisal* and *mood*:

$$coping(t+\Delta t) = coping(t) + \alpha\,reflection(t) \cdot w_{reflection}(t) \cdot (1 - |appraisal(t)\text{-}mood(t)|\,) \cdot (1 - coping(t))\,\Delta t$$

In addition, the openness for CBT is increased by reflection in the same manner as the openness for AS.

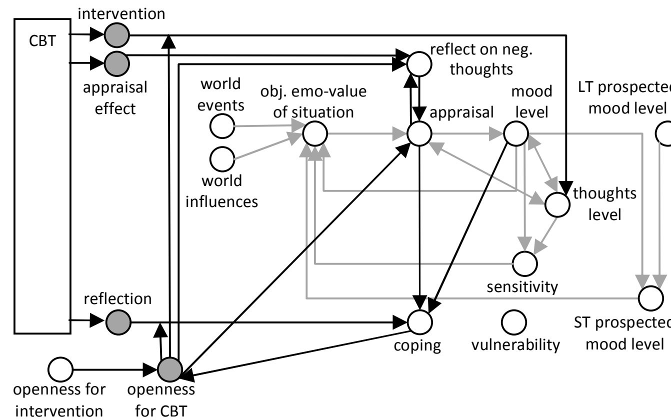

Fig.3. Computational Model for Cognitive Behavior Therapy

3.3 Intervention Directly Addressing Coping Skills and Vulnerability

The last type of intervention investigated is one which is assumed to affect coping skills and vulnerability directly. Such a type of intervention might be based, for example, on a belief that coping skills and vulnerability may be affected negatively by traumatic experiences in the past, and that these effects could be taken away or diminished by some form of therapy addressing these. For the moment ignoring questions such as whether existing therapies with such claims are effective, or would be possible at all, it still can be explored how such a type of therapy could work according to the computational model. This is shown in Figure 4. Here the impact of the therapy is modeled as a direct causal connection to coping skills and vulnerability.

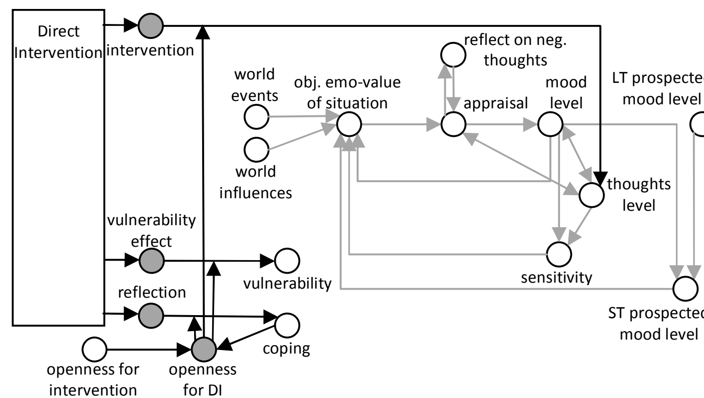

Fig.4. Computational Model for an Intervention Directly Addressing Coping Skills and Vulnerability

4 Simulation Results

In this section, simulation results are presented. Three different fictional persons are studied with divergent values for coping and vulnerability. Furthermore, the value for openness is varied for each of these persons as well (*0.2* and *0.3* for less and more openness respectively). These values are chosen to show the different influences of the therapies on different types of people and are in accordance with real persons who will follow the therapies in the future. Table 1 shows the initial values for the most important variables of the model for each person:

Table 1. Initial values for the simulation experiments

	person 1	person 2	person 3
coping	*0.1*	*0.15*	*0.3*
vulnerability	*0.9*	*0.85*	*0.7*
oevs	*0.925*	*0.907*	*0.84*
appraisal, mood, thoughts, sensitivity, short term prospected mood, long term prospected mood	*0.6*	*0.65*	*0.7*

For the sake of brevity, this section will only discuss the results for person 1. First, the simulation without any form of therapy is shown. The person experiences very negative events during a substantial period (with value 0.1 during 80 hours). Since the person is highly vulnerable, a depression follows. Note that time is represented in hours.

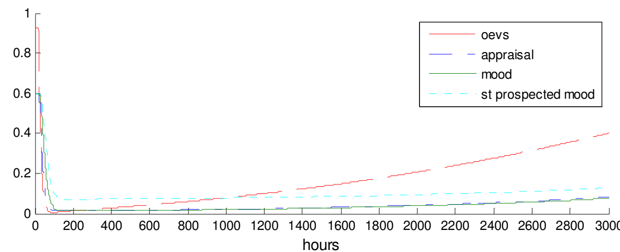

Fig.5. Person type 1 without therapy

The figure shows that a negative event of *0.1* is imposed on the person; this has a dramatic effect on all of the internal states of the patient: *mood* drops to a very low level and so do *appraisal* and the *short term prospected mood*. Eventually all states do start to increase again due to relatively good situations selected, but this goes very slowly.

Figure 6 shows an example whereby the patient is receiving cognitive behavioral therapy. The patient does however have a relatively low openness of *0.2* for this type of therapy.

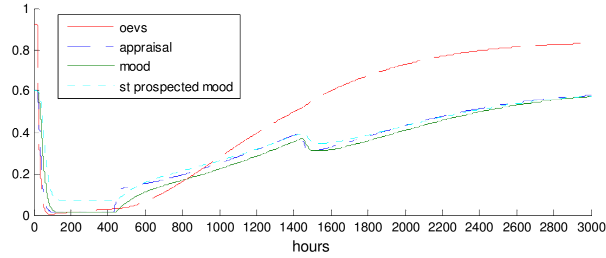

Fig.6. Person type 1 following CBT with a lower openness

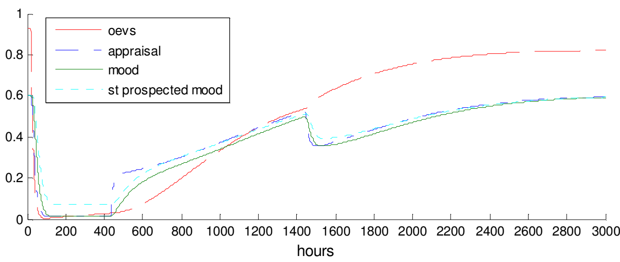

Fig.7. Person type 1 following CBT with a higher openness

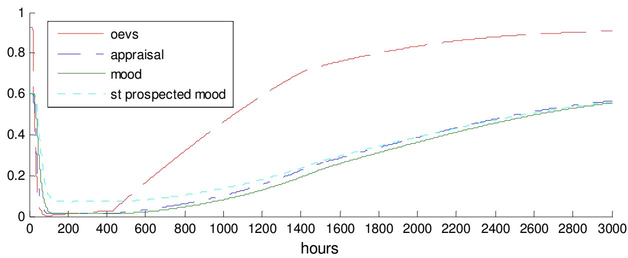

Fig.8. Person type 1 following AS with a lower openness

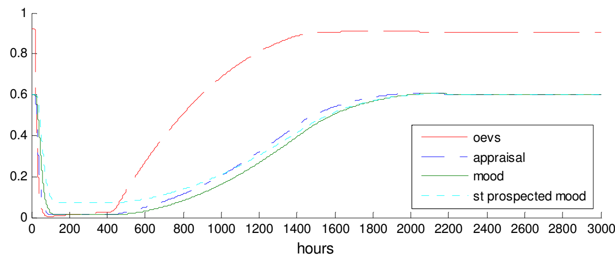

Fig.9. Person type 1 following AS with a higher openness

For this case, it can be seen that the *appraisal* is increased via reflection on negative thoughts, pulling the other states up as well. It does however still take quite some time to get the mood level sufficiently up. The dip after the intervention stops (after 6 weeks) is the result of the fact that the person is no longer reminded about the correctness/importance of appraisal, resulting in a slight search for a new equilibrium. If the openness is increased, the person recovers more quickly, because *reflection on negative thoughts* increases faster (see Figure 7).

For activity scheduling the same types of experiments have been conducted. Figure 8 shows an example of a person with a lower openness for this type of therapy. In this case, the world influence changes due to the therapy (since the therapy results in better situations being selected). This results in an increase of the *objective emotional value of situation*, pulling the rest of the states up as well. In case the person is more sensitive to the therapy, the *oevs* increases more quickly and therefore it takes less time for the person to recover (Figure 9).

Finally, in Figure 10 and 11 the results for the direct intervention are shown for a person with a low and high openness respectively. The figures show a more rapid recovery in case of a higher openness.

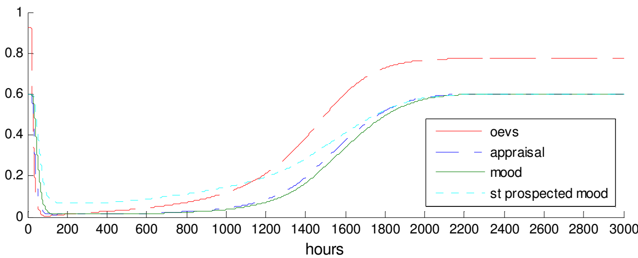

Fig.10. Person type 1 following a direct intervention with lower openness

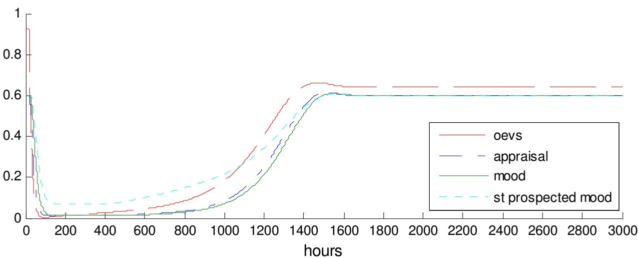

Fig. 11. Person type 1 following a direct intervention with higher openness

5 Analysis of the Computational Model

In this section, an analysis of the model described above is presented. Two different types of analysis have been performed, with partly different purposes. First, in order to verify the patterns produced by the model, a number of temporal patterns have been specified that reflect a number of general characteristics of the process of depression

and its treatment. For example, the characteristic that the length of a depression should be shorter for persons that follow a therapy than for people that did not follow a therapy. These properties have been automatically verified for different simulation traces of the model (Section 5.1).

Second, the effect of specific therapies on the change of the values for the different variables in the model has been analyzed. This analysis is also useful for verification of the intended effect of a therapy, but can be used for a different purpose as well. Based on the order in which different model variables start changing in reaction to a specific therapy, it is possible to derive which type therapy is given. Thus, this analysis forms a basis for a diagnostic process that can detect that a person follows some specific type of therapy, based on observations of values of variables that are present in the model (e.g., reports about the mood or an analysis of the objective emotional value of the situation). This part of the analysis is described in Section 5.2.

5.1 Verification

The following temporal properties that reflect a number of general patterns and characteristics of the process of depression and the treatment have been formulated. The properties were specified in the TTL language [4]. This predicate logical temporal language supports formal specification and analysis of dynamic properties, covering both qualitative and quantitative aspects. TTL is built on atoms referring to *states* of the world, *time points* and *traces*, i.e. trajectories of states over time. In addition, *dynamic properties* are temporal statements that can be formulated with respect to traces based on the state ontology Ont in the following manner. Given a trace γ over state ontology Ont, the state in γ at time point t is denoted by state(γ, t). These states can be related to state properties via the infix predicate |=, where state(γ, t) |= p denotes that state property p holds in trace γ at time t. Based on these statements, dynamic properties can be formulated in a sorted first-order predicate logic, using quantifiers over time and traces and the usual first-order logical connectives such as $\neg$, $\wedge$, $\vee$, $\Rightarrow$, $\forall$, $\exists$. For more details, see [4]. Automated tool support is also available that allows for verifying whether the properties hold in a set of simulation traces. A number of simulations (thereby considering all the different types of persons mentioned in Section 4 in combination with different openness to therapy) have been used as basis for the verification and were confirmed.

P1: Effectiveness of Therapy

Persons that follow a therapy are depressed for a shorter period than persons who do not.

∀γ1, γ2:TRACE, ∀ t:TIME
[[[state(γ1, t) |= intervention_CBT | state(γ1, t) |= intervention_AS] &
state(γ2, t) |= not intervention_AS & state(γ2, t) |= not intervention_CBT]
⇒ ∃t2:TIME > t, R1,R2 :REAL [R1 < MIN_LEVEL & R2 > MIN_LEVEL &
state(γ2, t2) |= has_value(mood, R1) & state(γ1, t2) |= has_value(mood, R2)]

P2: Openness to therapy helps

Persons more open to therapy remain depressed for a shorter period than those less open.

∀γ1, ∀γ2:TRACE, ∀ R1,R2: REAL, t:TIME
[[state(γ1 t) |= has_value(openness,R1) & state(γ2 t) |= has_value(openness,R2) & R2 < R1)]
⇒ ∃t2:TIME, R3,R4 :REAL [R3 < MIN_LEVEL & R4 > MIN_LEVEL &
state(γ2, t2) |= has_value(mood, R3) & state(γ1, t2) |= has_value(mood, R4)]

P3: Effect on coping skills

After a person has followed therapy for some time, the coping skills have improved.

∀γ:TRACE, t:TIME, R1:REAL
[[[state(γ, t) |= intervention_CBT | state(γ, t) |= intervention_AS)] & state(γ, t) |= has_value(coping, R1)]
 ⇒ ∃t2:TIME > t + MIN_DURATION, R2 :REAL
 [R2 > R1 + MIN_INCREASE & state(γ, t2) |= has_value(coping, R2)]

P4: CBT results in higher appraisal than AS

After a person has followed CBT, appraisal is higher than after following AS.

∀γ1, γ2:TRACE, ∀ R1,R2: REAL, t1, t2:TIME
[[state(γ1, t1) |= intervention_CBT & state(γ2, t1) |= intervention_AS &
 state(γ1, t2) |= has_value(appraisal, A1) & state(γ2, t2) |= has_value(appraisal, A2) &
 T2 > T1 + MIN_DUR] ⇒ A1 > A2]

This latter property was confirmed for persons with the same openness for therapy; those following AS with a high openness may end up with a higher appraisal than those following CBT with a low openness.

5.2 Effects of therapy types

In order to analyze the effect of the different types of therapies on the model variables, it is useful to see when a specific model variable starts changing as a result of the therapy, and in particular which variable changes first. The order in which the different concepts start being influenced by the treatment, is a characteristic of the therapy. For example, when following behavioral activation it is assumed that the *objective emotional value of the situation* will be affected before the mood itself will change. In contrast, cognitive behavioral therapy will first affect the *reflection on negative thoughts*. To detect the moment when an intervention affects a variable, we look at a sudden change in the increase or decrease of the value of a concept over time: a form of *acceleration*. Formally, this can be determined by looking at the relative second-order derivative of a variable over time: the second-order derivative divided by the first-order derivative. This can be calculated more easily by dividing the change of the value of a variable in the current time step ($t + \Delta t$) by the change of this value in the previous time step ($t - \Delta t$), as this is mathematically almost equivalent:

$$(y(t+\Delta t) - y(t)) / (y(t) - y(t-\Delta t)) - 1 \quad = \quad [\, (y(t+\Delta t) - y(t))/\Delta t \,] / [\, (y(t) - y(t-\Delta t))/\Delta t] - 1$$
$$= \; y'(t) / y'(t-\Delta t) - 1 \quad = \quad [y'(t) - y'(t-\Delta t)\,] / y'(t-\Delta t)$$
$$= [\, [[y'(t) - y'(t-\Delta t)\,]/\Delta t] / y'(t-\Delta t)\,] \;\; \Delta t \quad = \quad [\, y''(t-\Delta t)/y'(t-\Delta t)\,]\, \Delta t$$

So, to be precise, for mood this relative acceleration $y''(t-\Delta t)/y'(t-\Delta t)$ can be measured by:

$$mood_acceleration(t) = [(mood(t+\Delta t) - mood(t)) / (mood(t) - mood(t-\Delta t)) - 1] / \Delta t$$

The acceleration values for the concepts *mood*, *objective emotional value of the situation* and *reflection on negative thoughts* can be calculated similarly.

All acceleration values have been determined from 5 time steps before the start of the intervention till 15 time steps after the start. Figures 12 and 13 illustrate the order of change of the different variables for the different types of therapy. It can be seen that all therapies start having an effect at time point $t = 0$. Moreover, Figure 12 shows that AS indeed first affects the *situation* before the *mood* is affected. Similarly, CBT first affects the *reflection on negative thoughts* (Figure 13), however, this is a bit more

difficult to see. At $t = 0$, the acceleration of *reflection on negative thoughts* is very low (far below the bottom of the graph), because of the large increase of this concept at the start of the intervention. At $t = 1$ this value is almost zero (and therefore visible again in the graph), after which another dip follows at $t = 2$. This is because the concept stays at the high level for one time step and then starts dropping again, which can be seen in the left panel of Figure 13. However, the conclusion is that the reflection is influenced before the mood is affected.

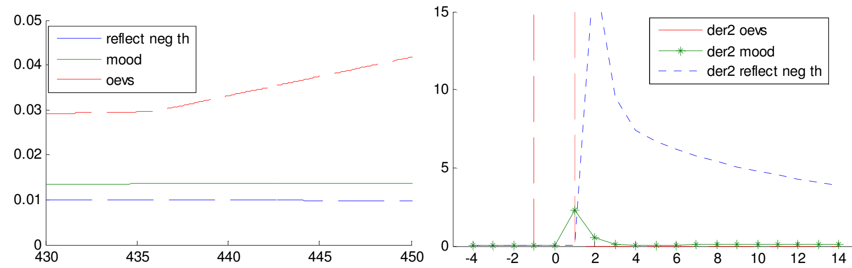

Fig.12. Original (left) and acceleration (right) of values for a patient following AS.

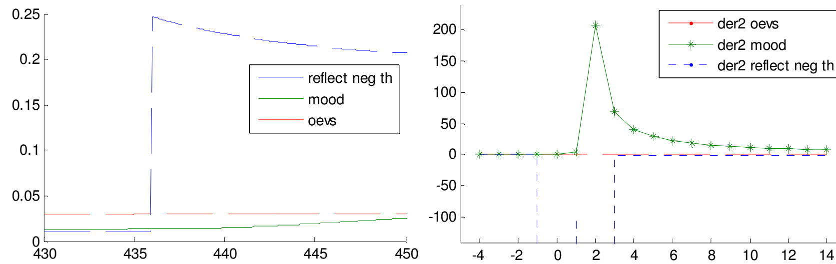

Fig.13. Original (left) and acceleration (right) of values for a patient following CBT.

6 Discussion

In this paper, a computational model has been presented for the effect of three different types of therapies for depression. It extends a computational model for human mood regulation and depression that has been developed in previous work [5]. Simulation results presented have shown how the mood regulation and depression indeed follow the expected patterns when applying these therapies. The intervention models have been analyzed for a variety of patient types by simulation experiments and formal verification.

This work is one of the first steps in the development of a software agent to support patients and the therapy followed during a depression in a personal manner. In future work these computational models will be integrated as a domain model within an agent model, in such a way that the agent is able to reason based on the domain model by causal deductive and abductive forms of reasoning. The aim is that in this way the

agent can both analyze the state of the patient and generate appropriate (inter)actions to the patient in order to improve the patient's state.

Acknowledgments. This research has been conducted as part of the FP7 ICT program of the European Commission under grant agreement No 248778 (ICT4Depression). Furthermore, the authors wish to thank Pim Cuijpers within the Department of Clinical Psychology at the VU University Amsterdam for the fruitful discussions.

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