# Incorporating an Ambient Agent to Support People with a Cognitive Vulnerability

**Azizi Ab Aziz[1], Michel C.A Klein[2]**
[1,2]Agent Systems Research Group, Department of Artificial Intelligence
Faculty of Sciences, Vrije Universiteit Amsterdam,
De Boelelaan 1081, 1081 HV Amsterdam, The Netherlands
E-mail:{mraaziz, michel.klein}@few.vu.nl

[1] Artificial Intelligence Research Group, School of Computing, College of Arts and Sciences, Universiti Utara Malaysia , 06010 UUM Sintok, Kedah, Malaysia
E-mail: aziziaziz@uum.edu.my

**Abstract:** This article presents the design of an intelligent agent application aimed at supporting people with a cognitive vulnerability to prevent the onset of a depression. For this, a computational model of the cognitive processes around depression is used. The agent application uses the principles of Rational Emotive Behavioural Therapy (RBET). The effect of the application is studied using software simulation. The simulation shows that a person that responds to REBT therapy develops less cognitive vulnerability than people that are not supported.

## 1. Introduction

In a modern life, affective disorder rank at the top of the most disturbing forms of mental illness [30]. Cognitive vulnerability is one of the main concepts that play an important role to escalate the risk of relapse in affective disorder (depression). In a broader spectrum, it is a defect belief, or structures that are persistently related for later emergent in psychological problems. This condition is in place long prior to the initial indication of affective disorder first become visible. It is important to understand this, since by addressing these precursors, the risk of recurrence can be reduced. Before further reviewing the underlying concepts of the vulnerability, it is essential to understand its connection between relapse condition in unipolar depression and social support [5]. Unipolar depression is a mental disorder, distinguished by a persistent low mood and loss of awareness in usual activities [8]. Normally, under a certain degree of stressors exposure, an individual with a history of depression will develop a negative cognitive content (thought), associated with the past losses [14]. Such cognitive content is often related to the maladaptive schemas, which in a long run will cause individual's ongoing thought capability to be distorted and later to be dysfunctional [29].

However, this cognitive distortion can be reduced through appropriate supports from other members within the social support network [22]. Social support network is made up of friends, family and peers. Some of it might be professionals and support individuals in very specific ways, or other people in this network might be acquaintances in contact with every day. It has been suggested that social support naturally can help to prevent and decrease stress through positive inferences, which later curbs the formation of cognitive vulnerability [3][7]. However, some literatures have shown that certain supports provide contrast effects [9][17][28]. Rather than attenuating the negative effects from stressors, it will eventually amplify the individual's condition to get worse [15]. Therefore it is important for an individual with a high level of cognitive vulnerability to be supported by a specific mean of intervention in order to prevent future onset.

The goal of this research is to develop an ambient agent application that can support people with a cognitive vulnerability to prevent the onset of a depression. To realize a supportive human agent application, it is required to integrate within the application a dynamical model of the human (domain model) that describes how an individual might experience cognitive vulnerability or could stay healthy. With that aim, a model of an ambient agent to support individuals with cognitive vulnerability is described, in which the domain model (cognitive model) is embedded [6]. The resulting integrative ambient agent is able to reason about the state of the human and the effect of possible actions. In case of vulnerability is predicted, the agent can provide to support by providing adequate remedies in an early stage. In addition, the aim of this article is to present the basis of an intelligent ambient agent application that complements the existing approaches by providing support to individuals with cognitive vulnerability using Rational Emotive Behavioural Therapy (REBT). This ambient agent application is expected to have capabilities to understand its environment and the individual, providing a better monitoring and assessment of the situation.

This article is structured as follows. After an introduction of the area of cognitive vulnerability, first the dynamical model for cognitive vulnerability is described in some detail and its behaviour analyzed by means of simulation, a mathematical analysis and an automated verification. Next, the integrative ambient agent model is described. It covers a number of sub-models used as building blocks. The main concepts of this model are specified, and results from simulation experiments are discussed and verified. Finally, a discussion concludes this article.

## 2. Fundamentals in Cognitive Depressogenic Thought

People vary in their abilities to overcome stressful life events and it allows them to manage their troubles and not be overwhelmed. These variations answer why the level of severity and duration among different individuals can be diverse in nature. To explain this mechanism, the Extended Hopelessness Theory of Depression is used. In this theory, people who exhibit a negative inferential style, in which they describe, attribute negative events to stable (likely to persist over time) and global (likely to affect many aspects of life) will most likely to infer themselves as fundamentally useless and flawed [1][2].

Although it is well documented that social support mitigates a risk of relapse, but there is a condition where feedbacks from the social support members may indirectly escalate the risk of relapse. Such feedbacks are considered as “maladaptive inferential feedback” (MIF), and normally increase the negative thought formation [3]. People who exhibit such negativity should be more likely to make negative conclusion regarding the causes of any stressful event they experience. Therefore, it will increase the likelihood to develop further cognitive damage. Contrary to this, an adaptive inferential feedback (AIF) provides a buffer to reduce the threat, by countering negative inferences for negative event [4]. AIF asserts that when a social support member offers comfort by attributing the source of negative event to be unstable, it will later diminish the risk of creating maladaptive inferences [18].

In addition, the Extended Hopelessness Theory of Depression relates the development cognitive depressogenic thought through previously described two precursors [25][26]. First, the present of positive social support feedback (AIF) acts as a buffer to decrease individuals’ possibility of having cognitive depressogenic thought over time. Second, individuals with cognitive depressogenic thought will make negative inferences when facing negative events. This condition is also associated with less AIF from the social support members. Moreover, both of these conditions capable to predict changes in stressful events. Therefore, it can be further used to elaborate the immunity level of individuals (as contrast in vulnerability concept). In addition, many studies have also associated the lower risk of depression with the presence of AIF [15].

As indicated in several previous works, inferential feedbacks provide one of the substantial factors towards the development of cognitive depressogenic thought over time. By combining either one of these two factors together with situational cues, it leads to the formation of either cognitive depressogenic inference or positive attributional style. Situational cues refers to a concept that explains individuals’ perception that highly influenced by cues from events (environment). Individuals under the influence of negative thought about themselves will tend to reflect these negative cognitions in response to the occurrence of stressors. These later develop the conditions called “stress-reactive rumination” and “maladaptive inference” [31].

Stress reactive rumination reflects a condition where individuals have difficulty in accessing positive information, and further develop a negative bias towards inference (maladaptive inference). It refers to “behaviours and thoughts that focus one’s attention one’s depressive symptoms and the implications of these symptoms” [24]. This process is amplified by previous exposures towards cognitive depressogenic thought episode. After a certain period, both conditions are related to the formation of hopelessness. Hopelessness is defined by the expectation that desired outcome will not occur, or there is nothing one can do to make it right [26]. Prolong and previous exposure from hopelessness will lead to the development of cognitive depressogenic thought. Evidence shows that negative cognitive style do indeed confer vulnerability to future onset. However, this condition can be reduced by having a positive attributional style, which normally existed during the presence of AIF and low situational cues perception [16].

In short, the following relations can be identified from the literature: *(1)* prolong exposure towards MIF, negative events, and high-situational cues can lead to the development of cognitive depressogenic thought. *(2)* a proper support (AIF) will reduce the risk of further development of future cognitive depressogenic thought. *(3)* Individuals with high situational cues and proper support will be less effective in reducing the progression of cognitive depressogenic thought, compared to the individuals with less situational cues.

## 3. A Dynamical Domain Model of Cognitive Depressogenic Thought

This section discusses the details of the dynamic model. In this domain model, three major components namely; environment, inferential feedbacks, and thought formation will represent the dynamic of interactions between social support feedback and individuals involved in negative thought formation during the beginning of relapse and recurrence in depression. In the formalization, those important concepts are translated into several interconnected nodes. These nodes are designed in a way to have values ranging from 0 (low) to 1 (high). Figure 1 depicts the global interaction between these nodes. The interaction will determine the new value of it, either by a series of accumulations or an instantaneous interaction for each node.

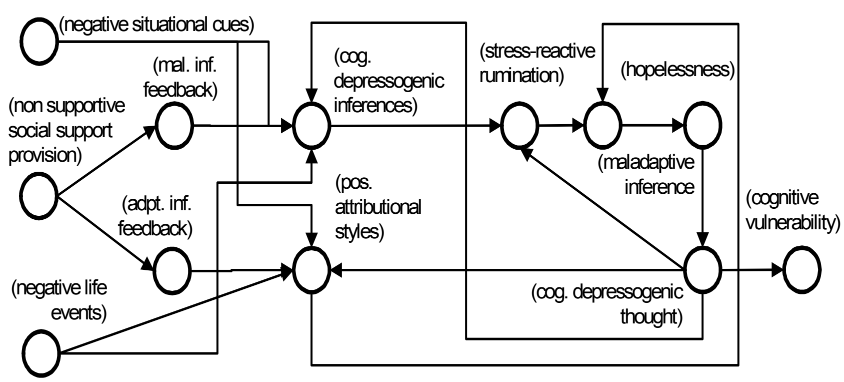


**Fig. 1.** Overview of the Domain Model in Cognitive Vulnerability

### 3.1 Ontology

To formalize the concepts of properties on dynamics relationship introduced in the previous section (Section 2), for each of them, a logical atom using predicate calculus is introduced; see Table 1. Note that all atoms make use of sorts. The specific sorts that are used in the presented model are AGENT, which represents an agent, and REAL, stands for the set of real numbers. To formalize the dynamic relationship between these concepts (as depicted in Fig. 1), the following temporal relationships are used.

**Table 1:** Formalization of Concepts Used for Model

| Concepts | Formalization |
|---|---|
| Life events | life_event(X:AGENT,R:REAL) |
| Chronic events | chronic_event(X:AGENT,R:REAL) |
| Daily events | daily_event(X:AGENT,R:REAL) |
| Negative events | neg_event(X:AGENT,R:REAL) |
| Situational cues | sit_cues( X:AGENT, R:REAL) |
| Adaptive inferential feedback | adapt_inf( X:AGENT, R:REAL) |
| Maladaptive inferential feedback | maladap_fb( X:AGENT, R:REAL) |
| Cognitive depressogenic inferences | cog_dep_inf(X:AGENT, R:REAL) |
| Positive attributional style | pos_att_style(X:AGENT, R:REAL) |
| Stress reactive rumination | sts_reactive(X:AGENT, R:REAL) |
| Maladaptive inference | maladap_inf(X:AGENT, R:REAL) |
| Hopelessness | hoplness(X:AGENT, R:REAL) |
| Cognitive depressogenic thought | cog_dep_tgt(X:AGENT, R:REAL) |
| Cognitive vulnerability | cog_vulnerability(X:AGENT, R:REAL) |

### 3.2 Temporal Specification

In order to develop a model, a temporal specification language called LEADSTO and its supporting software environment has been used. LEADSTO enables one to model direct temporal relationship between two state properties (dynamic properties). Consider the format of $\alpha \twoheadrightarrow_{e,f,g,h} \beta$, where $\alpha$ and $\beta$ are state properties in form of a conjunction of atoms (conjunction of literals) or negations of atoms, and e,f,g,h represents non-negative real numbers. This format can be interpreted as follows;

> If state $\alpha$ holds for a certain time interval with duration g, after some delay (between e and f), state property $\beta$ will hold a certain time interval of length h.

Here, atomic state properties can have a qualitative, logical format to represent certain observed conditions. In addition, this representation also holds a temporal trace$\gamma$, denoted by $\gamma \models \alpha \twoheadrightarrow_{e,f,g,h} \beta$, if

$$\forall t1[\forall t1[t1- g \leq t < t1 \Rightarrow \alpha \text{ holds in } \gamma \text{ at time t}]$$
$$\Rightarrow \exists d\ [e \leq d \ \leq f\ \&\ \ \forall t'\ [t1+ d \leq t' < t1 + d+ h]\ \Rightarrow\ \beta \text{ holds in } \gamma \text{ at time t'}]$$

For a more detailed discussion of this language, see [11]. To formalize the concepts of properties on dynamics relationship introduced in the previous section (Section 2), for each of them, a logical atom using predicate calculus is introduced. The following temporal relationships are used to formalize the dynamic relationship between those concepts.

**NEVT: Negative events**

A set of generated events is experienced by an agent X through simulation of several conditions using weighted sum *w* (where $\sum_w$=1) of life *L*, chronic *C*, and daily *D* events.

$\forall$X:AGENT

life_event(X,L) $\wedge$ chronic_event(X,C) $\wedge$ daily_event(X,D) $\wedge$ $w_1 \wedge$ $w_2 \wedge w_3$

$\twoheadrightarrow$ neg_event(X, $w_1$.L+ $w_2$.C+ $w_3$.D)

**PTS: Positive attributional style**

If the agent X faces bad situational cues *B*, negative events *Ne*, cognitive depressogenic thought *Cd*, adaptive inferential style *AiF*, and has a proportional contribution towards positive attributional style $\eta$ then the positive attributional style level is $\eta.AiF+(1-\eta).(1-(B.Ne.Cd))\ .AiF$

$\forall$X:AGENT

sit_cues(X, B) $\wedge$ neg_event(X, Ne) $\wedge$ adapt_inf(X, AiF) $\wedge$ $\eta$ $\wedge$ cog_dep_tgt(X, Cd) $\twoheadrightarrow$
pos_att_style(X, $\eta$.AiF+ (1-$\eta$).(1-(B.Ne.Cd)).AiF )

**CDI: Cognitive depressogenic inferences**

If the agent X experiences the intensity levels of experiences negative inferential style *MiF*, situational cues *B*, cognitive depressogenic thought *Cd*, negative events *Ne* and has a proportional contribution towards inferences $\alpha$ then the cognitive depressogenic inferences level is $\alpha.MiF + (1-\alpha).(B.Ne.Cd)).MiF$

$\forall$X:AGENT

sit_cues(X, B) $\wedge$ neg_event(X, Ne) $\wedge$ maladap _fb(X, MiF) $\wedge$ $\alpha$ $\wedge$ cog_dep_tgt(X, Cd) $\twoheadrightarrow$
cog_dep_inf (X, $\alpha$.MiF + (1-$\alpha$).(B.Ne.Cd)).MiF)

**STR: Stress reactive rumination**

If the agent X experiences the intensity levels of cognitive depressogenic thought *Cd*, and cognitive depressogenic inference *CDi* and has a proportional regulator $\beta$ then the stress reactive rumination level is $\beta.\ CDi + (1-\beta).\ Cd$

$\forall$X:AGENT

cog_dep_inf (X, CDi) $\wedge$ cog_dep_tgt(X, Cd) $\wedge$ $\beta$ $\twoheadrightarrow$ sts_reactive(X, $\beta$. CDi + (1-$\beta$). Cd )

**MDI: Maladaptive inference**

If the agent X faces stress reactive rumination in SR level and perceives positive attributional style PS level and has a proportional contribution regulator $\gamma$ then the maladaptive inference level is $\gamma.SR\ .(1-PS)$

$\forall$X:AGENT
sts_reactive(X, SR) $\wedge$ cog pos_att_style(X, PS) $\wedge$ $\gamma$ $\twoheadrightarrow$ maladap _inf(X, $\gamma$.SR .(1-PS))

**CV: Cognitive Vulnerability**
If the agent X experiences the intensity levels of cognitive depressogenic thought *Cd*, and has previous level of cognitive vulnerability *Cv* and has an adaptation rate $\lambda$ then the cognitive vulnerability for agent X after $\Delta t$ is *(Cv + $\lambda$.(1-Cv).(Cd-Cv).Cv.$\Delta$t)*
$\forall$X:AGENT
cog_dep_tgt (X, Cd) $\wedge$ cog_vulnerablity(X, Cv) $\wedge$ $\lambda$ $\twoheadrightarrow$ cog_vulnerablity(X, Cv + $\lambda$.(1-Cv).(Cd-Cv).Cv.$\Delta$t)

**HPS: Hopelessness**
If the agent X faces level of maladaptive inference *MDi* and has previous level of hopelessness *Hp* and has adaptation rate $\psi$ then the hopelessness level for agent X after $\Delta t$ is *Hp + (1-Hp).$\psi$.(MDi-Hp).Hp.$\Delta$t*
$\forall$X:AGENT
maladap _inf(X, MDi) $\wedge$ hoplness(X, Hp) $\wedge$ $\psi$ $\twoheadrightarrow$ hoplness(X, (1-Hp).$\psi$.(MDi-Hp).Hp.$\Delta$t)

**CD: Cognitive depressogenic thought**
If the agent X faces level of hopelessness *Hp* and has previous level of cognitive depressogenic thought *Cd* and has an adaptation rate $\varphi$ then the cognitive depressogenic thought level for agent X after $\Delta t$ is *Cd + (1-Cd).$\varphi$.(Hp-Cd).Cd.$\Delta$t*
$\forall$X:AGENT
hoplness(X, Hp) $\wedge$ cog_dep_tgt (X, Cd)$\wedge$ $\varphi$ $\twoheadrightarrow$ cog_dep_tgt (X, Cd + (1-Cd).$\varphi$.(Hp-Cd).Cd.$\Delta$t)

## 4. Simulation Results

In this section, the model was executed to simulate several conditions of agents with the respect of exposure towards negative events, feedbacks from the social support members, and situational cues. With variation of these conditions, some interesting patterns can be obtained, as previously defined in the earlier section. For simplicity, this article shows several cases of cognitive depressogenic thought levels formation using three different agent attributes. These cases are; (i) an agent ***Heidi*** with a good feedback from the social support members, and using a good judgment about the situation (*B=0.2, MiF=0.1, AiF=0.8)*, (ii) an agent ***Kees*** that receives good feedbacks but with bad judgment about the situation (*B=0.8, MiF=0.1, AiF=0.9)*, and (iii) an agent ***Piet*** with bad feedbacks from the social support, and bad judgment about the situation (*B=0.9, MiF=0.8, AiF=0.1*). The duration of the simulated scenario is up to $t$ = 1000 (to represent the conditions within 42 days) with three negative events. The first event consisted of the prolonged and gradually decreased stressors, the second event dealt with the decreased stressor, while the third event simulated repeated stressors. For all conditions, the initial cognitive depressogenic thought was initialized as 0.5.

**Case #1: Prolonged Repeated Stressor with Different Individuals Inferential Feedback and Situation Cues**

During this simulation, each type of individual attribute has been exposed to a prolonged stressor condition. The result of this simulation is shown in Figure 2.

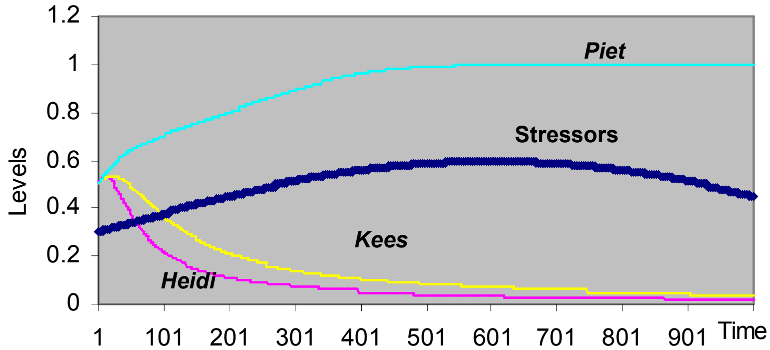


**Fig. 2.** Cognitive Depressogenic Level for Each Individual during Prolonged Stress Events

In this simulation trace, it shown that *Piet* (*high situational cues,* and *negative inferential feedback*) tends to develop a cognitive depressogenic thought, in contrast with the others. *Heidi* (*low situational cues,* and *positive inferential feedback*) shows a rapid declining pattern in developing the cognitive condition. Note that *Kees* (*high situational cues* and *positive inferential feedback*) has also developed a decreasing pattern towards the cognitive condition. However, *Kees* has a lesser decreasing effect towards a negative thought despite a high positive support, given that this individual tends to perceive negative view about the situation. Persistent positive support from the social support members helps each agent to reduce the development of cognitive thought throughout time

**Case #2: Decreased Stressor with Different Individual Inferential Feedback and Situational Cues**

In this simulation trace, there are two conditions were introduced, one with a very high constant stressor, and with no stressor event. These events simulate the condition of where agents were facing a sudden change in their life, and how inferential feedbacks and perceptions towards events play important to role towards the diminishing of cognitive thought. The result of this simulation is shown in Figure 3.

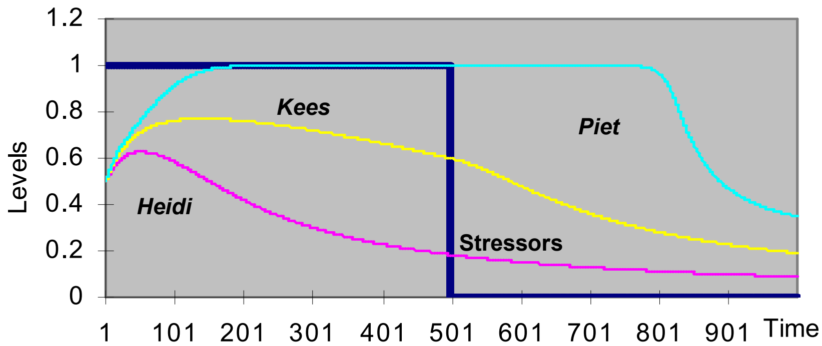


**Fig. 3.** Cognitive Depressogenic Level for Each Individual during Fluctuated Stressors

A comparison for each agent shows that *Piet* gets into a sharp progression towards a high cognitive thought after direct exposure towards a heighten stressor. At the start of a high constant stressor, both individuals *Heidi* and *Kees* develop cognitive thought. However, after certain time points, those progressions dropped and reduced throughout time. As for *Piet*, even the stressors have been diminished; the level cognitive depressogenic thought was still high for several time points until it decreased.

**Case # 3: Rapid Repeated Stressors with Different Individual Inferential Feedback and Situational Cues**

For this simulation, each type of individual has been exposed to a stream of repeated stressors, with a rapid alteration between each event. In a real situation, it simulates the cummulative effect conditions, where repeated strikes had the effect of escalating the overall intensity of stressors.

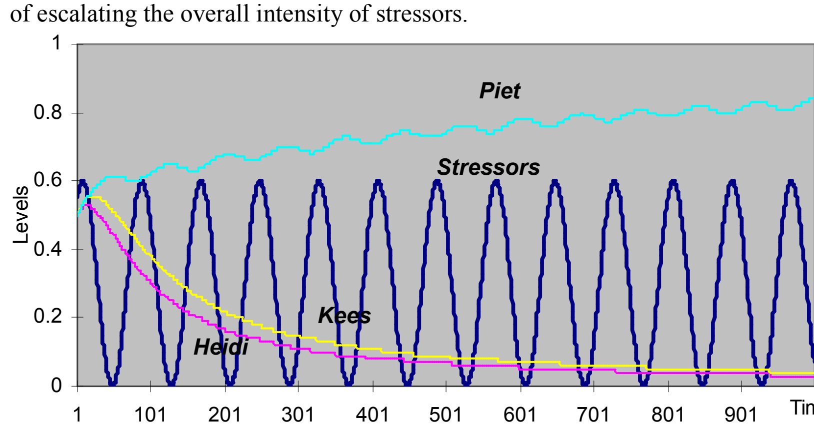


**Fig. 4.** Cognitive Depressogenic Level for Each Individual during Repeated Stressors

Figure 4 illustrates the effects of repeated stressors condition towards different individuals. Note that *Piet* develops a gradual increasing level of cognitive thought, while both *Heidi* and *Kees* show a contrast effect. Using a similar experimental setting, by using $t_{max}$=5000, the end of the experimental results show *Piet* will have a persistent cognitive depressogenic value equal to 1.

## 5. Mathematical Analysis

By a mathematical formal analysis, the equilibria of the model can be determined. The equillibria explains condition where the values for the variables which no change occur. One important assumption should be made; all exogenous variables are having a constant value. Assuming all parameters are non-zero, the list of LEADSTO specifications for the case of equilibrium for the agent X are:

$$dCd(t)/dt=(1-Cd).\varphi.(Hps-Cd).Cd \quad \textbf{(1)}$$
$$dHp(t)/dt = (1-Hp).\psi.(MDi-Hp).Hp \quad \textbf{(2)}$$

Next, the equations are identified describing

$$dCd(t)/dt= 0,\ dHp(t)/dt = 0$$

Assuming both adaptation rates are equal to 1, therefore, these are equivalent to;

$$Cd=1 \text{ or } Hp=Cd \text{ or } Cd=0 \quad \textbf{(3)}$$
$$Hp =1 \text{ or } MDi=Hp \text{ or } Hp=0 \quad \textbf{(4)}$$

From here, a first of conclusions can be derived where the equilibrium can only occur when the Cd= 1, *Hp*=*Cd*, or *Cd*=0 (refer to Equation 3). By combining these three conditions, it can be re-written into a set of relationship in $(A \vee B \vee C) \wedge (D \vee E \vee F)$ expression:

$$(Hp =1 \vee MDi=Hp \vee Hp=0) \wedge (Cd=1 \vee Hp=Cd \vee Cd=0) \quad \textbf{(5)}$$

This expression can be elaborated using the *law of distributivity* as $(A \wedge D) \vee (A \wedge E) \vee, \ldots, \vee (C \wedge F)$. This later provides possible combinations equillibria points to be further analyzed. In this article, only condition *Cd*=1, *Cd*=0 have been chosen for the discussion. From this case (*Cd*=1), it can be further derived that respective values for the equilibrium condition to take place. These values can be calculated from the following formulae.

$$CDi = \alpha.MiF + (1-\alpha).(B.Ne.Cd).MiF$$
$$PS = \eta.AiF + (1-\eta).\ (1-(B.\ Ne.Cd)).AiF$$
$$SR = \beta.[\alpha.MiF + (1-\alpha).(B.Ne.Cd).MiF] + (1-\beta)$$
$$MDi = \gamma.[\beta.(\alpha.MiF + (1-\alpha).(B.Ne.Cd).MiF] +(1-\beta)).(1-(\eta.AiF+(1-\eta).(1-(B.Ne.Cd))).AiF)]$$

This equillibria describes the condition when agents are experiencing an intense negative cognitive thought throughout time will eventually have their cognitive vulnerability level high to the limit. This condition creates higher vulnerability towards the development of onset during the present of negative events. It also represents the conditions where individuals with high maladaptive inferential feedbacks and situational cues levels over prolong period tend to develop cognitive depressogenic thought. Simulation trace from the experiment #1 confirms this condition. Another special case of an equilibrium condition is when *Cd*=0. In this case, the following values are found:

$CDi = \alpha.MiF$
$PS=\eta.AiF$
$SR = \beta.(\alpha.MiF)$
$MDi = \gamma.\beta.(\alpha.(MiF).(1-\eta.AiF)$

From this, it is an equilibrium, which would be considered as a good condition since the stable individuals' describes agents with a good mental condition (less vulnerable towards stressors). Having this, it shows that agents with high adaptive inferential feedbacks and low situational cues tend to have a low cognitive depressogenic thought level even during prolonged exposure towards stressors. Some parts of the simulation trace from the experiment #2 verify this condition. This condition is imperative to reduce the formation of potential relapse / recurrence caused by negative events.

For the equilibrium case when *Hp=Cd*, the following values are found:

$CDi = \alpha.MiF + (1-\alpha). (B.Hp.Ne). MiF$
$PS=\eta.AiF + (1-\eta).(1-(B.Ne.Hp)).AiF$
$SR = \beta.(\alpha.MiF + (1-\alpha).(B.Hp.Ne).MiF) + (1-\beta).Hp$
$MDi=\gamma.[\beta.(\alpha.MiF+(1-\alpha).(B.Hp.Ne). MiF) +$
$(1-\beta).Hp.(1-(\eta.AiF + (1-\eta)).(1- (B.Ne.Hp)).AiF)]$

This equilibrium condition represents where the individuals remain constant in a cognitive depressogenic thought state over time points. Similarly, formulae can be derived for the other cases in Equation 5.

## 6. Automated Verification for the Domain Model

This section deals with the verification of relevant dynamic properties of the cases considered in the human agent model, which coherence with the literatures. The Temporal Trace Langue (TTL) is used to perform an automated verification of specified properties against generated traces. TTL is designed on atoms, to represent the states, traces, and time properties. This relationship can be presented as a *state(γ, t, output(R))* |= *p*, means that state property *p* is true at the output of role *R* in the state of trace *γ* at time point *t* [10]. Based on that concept, several dynamic properties can be formulated using a sorted predicate logic approach. Below, a number of them are introduced in semi formal and in informal representations.

**VP1: Positive supports will reduce the risk in developing future depressogenic thought**

When an agent X received more positive supports from its social support networks, then the agent will unlikely to develop further hopelessness in future.

VP1 ≡ ∀γ:TRACE, t, t':TIME, R1,R2,R3,MIN_LEVEL:REAL, X:AGENT
[ state(γ, t) |= adapt_inf (X, R1) & R1 > MIN_LEVEL
state(γ, t) |= cog_dep_tgt (X,R2) & R2 > 0]
⇒ ∃t':TIME > t:TIME

[state(γ, t') |= cog_dep_tgt (X,R3) & R3 < R2]

This property can be used to verify future condition of an agent if the agent receives positive supports from its social support members throughout time. Many research works have maintained that positive supports from members will decrease possibilities of having further negative thought in future [22].

**VP2: Negative perception towards situation and bad support received from the social support networks will increase the risk of further depressogenic thought.**

When an agent X perceives all situations will give negative impact and an agent X receives bad support from its social support networks, then the agent X will almost likely to develop future depressogenic thought.

VP2 ≡ ∀γ:TRACE, t, t':TIME, R1,R2,R3,R4, MIN_MLD_LEVEL, MIN_SC_LEVEL, MAX_CDT_LEVEL:REAL, X:AGENT
[state(γ, t) |= maladap_bf (X, R1) &
R1 > MIN_MLD LEVEL &
state(γ, t) |= sit_cues(X, R2) & R2 > MIN_SC_LEVEL &
state(γ, t) |= cog_dep_tgt (X,R3) & R3 < MAX_CDT_LEVEL]
⇒ ∃t':TIME > t:TIME
[state(γ, t') |= cog_dep_tgt (X,R4) & R4 > R3]

By checking property VP2, one can verify whether negative perception (situational cues) and bad support will influence the rise of depressogenic thought. It is particularly significant to observe this property in the model given that bad support and negative perception is highly correlated towards the development of depressogenic thought [16].

**VP3: Prolong exposure towards negative events, cognitive depressogenic thought, and bad support will increase the level of agent's cognitive vulnerability.**

When an agent X is experiencing prolong exposure towards negative events, high cognitive depressogenic thought, and bad support, then the cognitive vulnerability level of an agent X will be increased.

VP3 ≡ ∀γ:TRACE, t, t':TIME, R1,R2,R3,R4, R5, MIN_CDT_LEVEL, MIN_MLD_LEVEL :REAL, X:AGENT
[state(γ,t) |= neg_event (X, R1) & R1 > 0.7 &
state(γ,t)|= cog_dep_tgt (X, R2) & R2 > MIN_CDT_LEVEL
state(γ, t) |= maladap_bf (X, R3) & R3 > MIN_MLD LEVEL
state(γ, t) |= cog_vulnerability (X, R4) ⇒
∃t':TIME > t:TIME
[state(γ, t') |= cog_vulnerability (X, R5) & R5 ≥ R4]

This property can be used to check whether the cognitive vulnerability level will increase after a certain period of time, due to the exposure of above conditions.

## 7. Rational Emotive Behavioral Therapy

The intelligent agent application will provide support based on the ideas in the Rational Emotive Behavioural Therapy (REBT). This section will describe this therapy. In general, REBT is a comprehensive and active-directive psychotherapy which focuses on resolving emotional and behavioral problems and disturbances and enabling people have positive belief in their life [20]. One of the most important concepts in REBT is that humans, in most cases, do not merely get upset by unfortunate adversities, but also by how they construct their beliefs the events, themselves and other [19].

### 7.1 Important Concepts in REBT

REBT suggests that human beings defeat or distub themselves in two main ways: (1) by holding irrational beliefs about their self (ego disturbance) or (2) by holding irrational beliefs about their emotional, social, or physical comfort (discomfort disturbance) [20]. To overcome these disturbances, REBT employs the 'ABC framework' to clarify the relationship between activating events and individual's beliefs (A); individual's beliefs about them (B); and the cognitive, emotional or behavioural consequences of our beliefs (C) [19][20]. These steps are dispute irrational beliefs D), and implement new effective thinking (E). Using this extended concept, individual will try to understand the role of their mediating, evaluative over unrealistic interpretations and assumptions in upset [23]. Later, he or she often can learn to identify their irrational beliefs, challenge and question them. It will allow individual to distinguish them from unhealthy scenarios, and use more constructive and self-helping constructs. Figure 4 depicts these interactions.

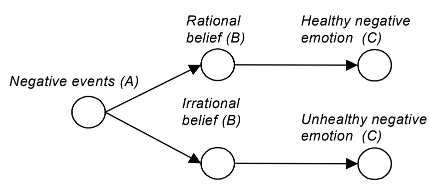


**Fig. 4.** Interactions in ABC framework.

### 7.2 Techniques

There are several techniques that can be adopted to alter irrational belief about the events, namely; cognitive, behavioural, and imaginary techniques. Cognitive techniques focus to detect irrational beliefs, to separate the rational from the irrational and to change one's way of thinking, while behavioural approaches are used to develop more effective ways of thinking by entering feared situations that individual would normally avoid. Imaginary techniques are designed to show that one's life and the world in general, continue after a feared or unwanted event has come and gone by visualizing the future outcomes of it. A complete description of these techniques is available in [19][23].

## 8. Ambient Agent Model

In order to achieve an intelligent agent, an approach has been followed in which the dynamical domain model for depression is integrated in the model that describes the functioning of the ambient agent. Here ambient means in the immediate environment of humans that are supported by them, for example, on their cell phone [13]. This integration takes place by embedding domain models in certain ways within agent models. By incorporating domain models within an agent model, the agent gets an understanding of the processes of its surrounding environment, which is a solid basis for knowledgeable intelligent behaviour. It is important to have such capabilities, since an ambient agent should be aware of human behaviours and states [6]. Through this mechanism, the agent will use this vital knowledge to provide appropriate actions related to the predicted state of the human and the environment [32]. Such understanding enables them to perform actions in a more informed, knowledgeable manner, and to show more human-like behaviour in interaction with humans [12].

In this case, a domain model that describes human processes and behaviour is used directly as an agent model, in order to simulate human behaviour. Note that here the domain model and agent model refer to the same agent. In addition to this, the *analysis model* is used *t*o perform analysis of the human's states and processes by reasoning based on observations (possibly using specific sensors) and the domain model [6]. Another model, namely the *support model* aims to generate support for the human by reasoning based on the domain model.

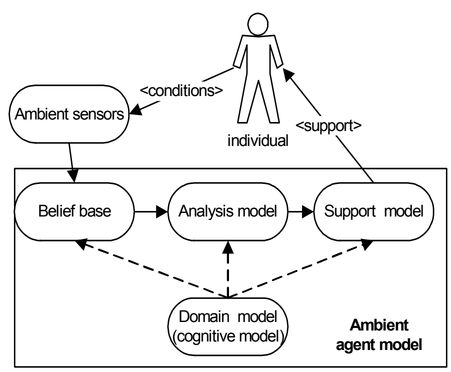


**Fig. 5.** Overview of the ambient

In Fig. 5, the solid arrow indicates information exchange between processes, and the dotted arrow represents the integration process of the domain model within the ambient agent models. The detailed view of the model is shown in Fig. 6.

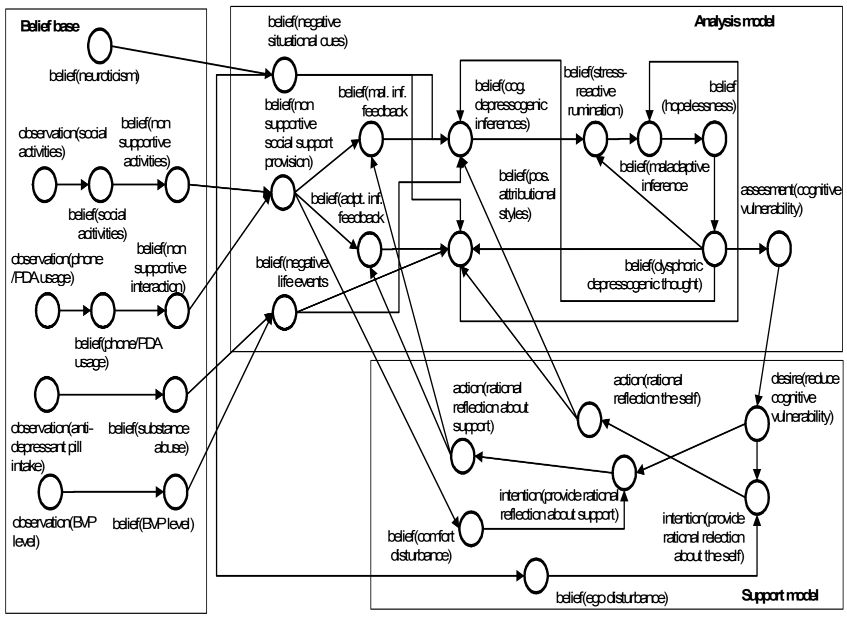


**Fig. 6.** Detailed Interactions within an Ambient Agent Model

Technically, the Belief-Desire-Intention (BDI) structure represents the beliefs as corresponding to information the agent has about the world, while desires correspond to states of actions that the agent would wish to be executed, and intentions represent actions that the agent has committed to accomplish [6]. Figure 7 depicts the overall functioning of the BDI model

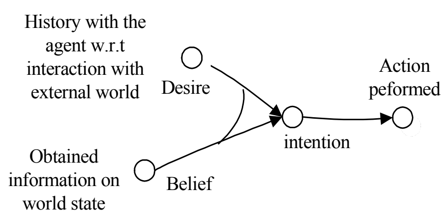


**Fig. 7**, The BDI structure

The term *belief* represents that what an agent believes about the world (or another agent) may not necessarily be true all the time and may change over time. As for the integrative agent model, the BDI structure will be used as a foundation for most of the properties.

### 8.1 Belief Base

The main principle of the belief base is to construct primary beliefs (basic and derived beliefs) from the ambient agent's observation about the individual's condition. Information about individual's condition can be obtained from a number of ambient sensors and devices [6]. For example, basic beliefs refer to beliefs related to the sensors (from the environment), while derived beliefs are based on derivations using the domain model. One of the advantages to have such concept is it allows potential extension of the model. In this case, if there is a new way (or sensors) can be used to measure belief in substance abuse, it is easily can be added as a basic belief for a new observation, and append it with the existing substance abuse belief. Furthermore, another belief model can make use this set of related beliefs without having to produce a new one.

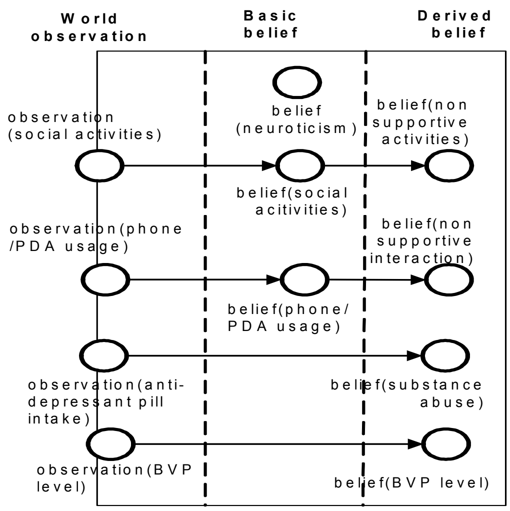


**Fig. 8.** Belief base

In the presence of pervasive and wearable technologies, such conditions can be observed through several ambient sensors and devices. For example, a medicine box that registers medication intake (MEMS) and passive alcohol sensors can used to observe potential substance abuse, while a mobile phone / personal digital assistant (PDA), digital planner, and email interaction provide essential cues to monitor social activities [6][21][33]. In addition to this, using blood pressure sensor provides important information to infer those individuals are experiencing potential stress [27]. These devices can potentially be integrated to support the real world application. However, a detailed discussion on these devices and signals is beyond the scope of this article.

### 8.2 Analysis Model

One of the very important elements of ambient agents is that they collect and infer information about the human's functioning. Some aspects of the states and processes related to the human's functioning can be directly observed, but often many relevant aspects only can be indirectly derived. For such derivations it is useful to have a domain model integrated within the ambient agent model in the form of an *analysis model*. In this model, one of the important features to determine the level of cognitive vulnerability is the continuous assessment of changes in selected physiological and behavioural features within the individual.

This assessment is highly related to the domain (cognitive) model encapsulated within the analysis model [12]. Using this cognitive model in the analysis model, the progression of the important features is analyzed. If the individual cognitive vulnerability level (from the assessment) is above the accepted threshold level for certain individual (*baseline threshold*), then the model will consider he/she is in the risk of experiencing an onset. By analyzing this condition, an agent will interfere this maladaptive progression by trigger desire to reduce an individual's cognitive vulnerability. This later will trigger the support model.

### 8.3 Support Model

For an ambient agent to have some beliefs and assessments about the human's internal state is one thing, but to be of any help also actions are needed to avoid undesirable states. To generate actions that fit to the results of the analysis, a *support model* can be used by the ambient agent. In this case, an individual at a high risk of cognitive vulnerability, necessary actions are needed to curb the onset stage. The ambient agent can use the results from analysis model to generate support actions for the individual. Information about beliefs in non-supportive social support provision and negative situational cues can used to select an appropriate action. This important information will lead to the agent's beliefs either an individual is experiencing ego-disturbance (from belief in negative social cues) or comfort disturbance (non-supportive social support provision). For example, if the belief non-supportive social support provision holds true, then the agent perceives the individual is experiencing comfort disturbance.

By triggering belief in comfort disturbance, an agent generates an intention to support an individual. Later, by combining this intention with the desire to reduce an individual's cognitive vulnerability, an agent will provide a RBET intervention for both actions (to support action in rational reflection about support or about the self). As a result from this intervention process, it will curb the development of future irrational beliefs, and later provides effective new thinking on individual experienced conditions. In the domain model, the intervention effect from beliefs in comfort disturbance is calculated as follows.

$$MiF^{+}(t) = NsP(t).(1-RtO(t)) \quad \textbf{(6)}$$

$$AiF^{+}(t)= (1-(1-RtO(t)).NsP(t)) \quad \textbf{(7)}$$

where $MiF^{+}(t)$ and $AiF^{+}(t)$ *represent individuals condition* during intervention process for comfort disturbance. Moreover, the effect of intervention on beliefs in ego disturbance can be seen in these formulations.

$$PtS^{+}(t) = [\eta.AiF(t) + (1\text{-}\eta).\ (1\text{-}\ (SiC(t).\ DyT(t).NvT(t)(1\text{-}RtS(t)))].AiF(t) \quad \textbf{(8)}$$

$$CdI^{+}(t)=[\alpha.MiF(t) + (1\text{-}\ \alpha).\ SiC(t)\ DyT(t).MiF(t)].(1\text{-}RtS(t)).NvT(t) \quad \textbf{(9)}$$

where *RtO* and *RtS* functions represent the conditions to simulate the effects of intervention when any individual is experiencing distorted beliefs and receiving the support provided by an ambient agent. $PtS^{+}(t)$ and $CdI^{+}(t)$ computes the effect of this intervention in ego disturbance cases. These functions simulate three conditions; *(1)* an individual with a good skill to dispute the irrational belief, *(2)* an individual in a learning process and later acquired the skills, *(3)* an individual without any therapy skills and avoiding help.

## 9. Simulation Traces

The intervention as described in the previous section has been implemented in simulation environment. Using this simulation environment, we mimicked the intervention process to see its effect under several cases. Three scenarios are shown: an agent supports  a individual with good skills in using cognitive techniques to the dispute distorted belief (***A***), an agent support with a individual who is new with RBET, learns the techniques, and later acquire the important skills to dispute the distorted belief ***(B)***, and a individual who refuse to accept help and incapable to acquire important skills to dispute the belief (***C***). These scenarios are studied under several negative events, namely; prolonged, repeated, and fluctuated events. In all cases, the temporal relations are initialized at 0.5. Corresponding to these settings, the level of severity (baseline to consider as a cognitive vulnerably condition) is set at 0.3, defining that any individuals scoring higher than 0.3 in their cognitive vulnerability level will be considered as experiencing difficulties and need help.

In addition, these simulations used the following parameters settings: $t_{max}$=1000 (to represent a monitoring activity up to 42 days), $\Delta t$=0.3, all proportional and flexibility rates are assigned as 0.5 and 0.9 respectively. These settings were obtained from several systematic experiments to determine the most suitable parameter values in the model.

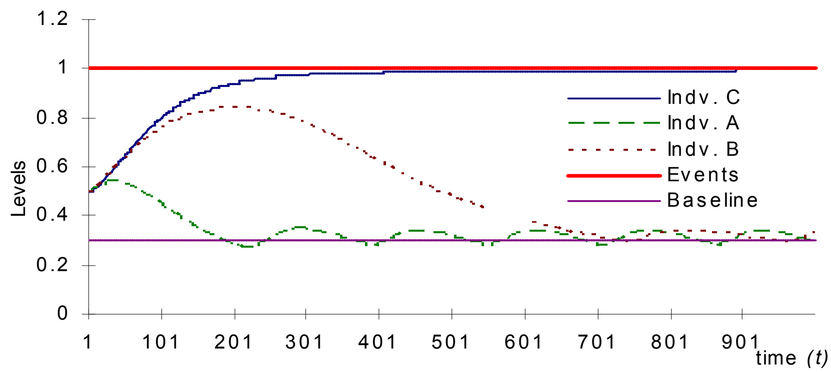


**Fig. 8.** Cognitive Vulnerability Level for Each Individual (prolonged stressors)

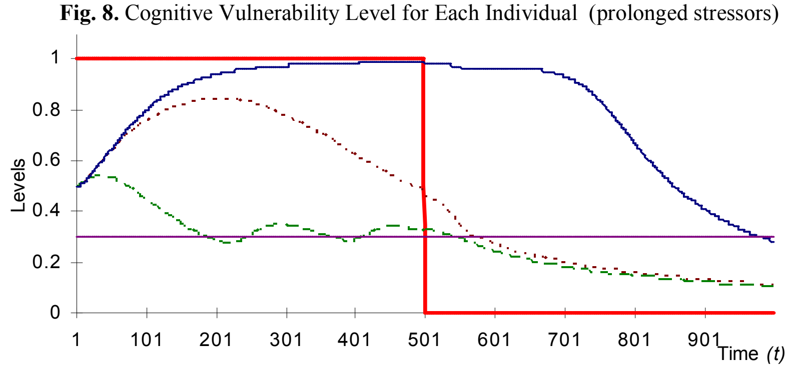


**Fig. 9.** Cognitive Vulnerability Level for Each Individual (fluctuated negative events)

*Prolonged Negative Events*

During this simulation, each type of individual has been exposed to the highly extreme and constant negative events. In this simulation trace it shown that an individual *C* tends to experience cognitive vulnerable condition much faster compared to other people. Furthermore, the individual *C* also experienced persistent cognitive vulnerability throughout the development of negative events. As for the individual *B*, in the beginning of the simulation, individual *B* is experiencing the increasing effect towards cognitive vulnerability. However, after certain time point, note that an individual *B* shows a gradual decreasing level from potential cognitive vulnerability. Individual *A* is capable to lower the risk of cognitive vulnerability within the baseline boundary. The simulation results for these conditions are shown in Fig. 8.

*Fluctuated Stressor Events*

This simulation trace shows two types of periods, one with a very high constant and with a very low constant stressor event. These events occurred in a constant behaviour for a certain period of time (approximately within 20 days). Fig. 9 illustrates how each individual reacts with these conditions. Although all individuals show a full recovery state during the end of the simulation period, but for individual *C* it takes longer period to reach that particular state and it is only happens after the negative events (stressors) have diminished. Both individuals *A* and *B* show faster progression towards recovery compared to an individual *C*.

*Repeated Stressor Events*

During this simulation, all individuals are exposed to repeated negative events, that later will decline gradually. These conditions represent an individual is experiencing an extreme stream of stressor events, with a rapid alteration between each corresponding event.

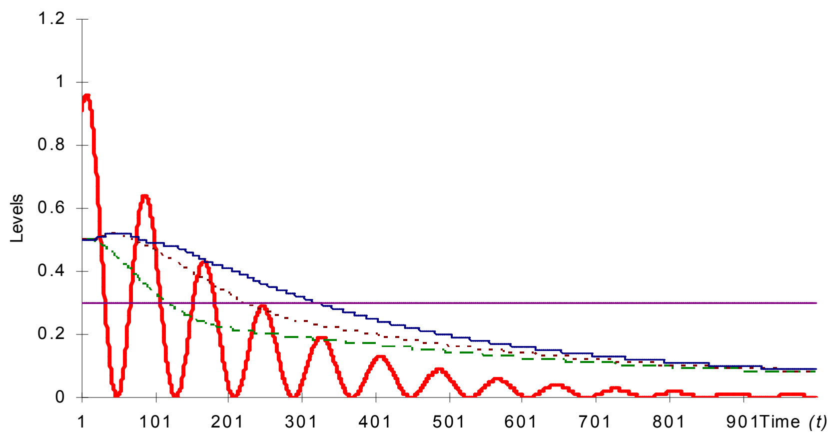


**Fig. 10.** Cognitive Vulnerability Level for Each Individual (repeated negative events)

As can be seen from Fig. 10, when the stressors decrease, all individuals show decreasing patterns in their cognitive vulnerability. However, an individual *C* has shown a slow decline progression towards a full recovery stage.

## 10. Automated Verification for the Ambient Agent Model

This section deals with the verification of relevant dynamic properties of the cases considered in the ambient agent model. It is important to verify whether the model produces results that are coherent with the literature and appropriate to help the patient.

**VP4: Individuals with Good Skills in RBET will Reduce the Risk of Future Cognitive Vulnerability**

When an individual capable to perform good skills in RBET, then the individual will unlikely to develop further cognitive vulnerability in future.

VP1 ≡ ∀γ:TRACE, t, t':TIME, R1,K1,V1,V2, MIN_LEVEL_SELF,
MIN_LEVEL_SUPPORT:REAL, X:AGENT
[state(γ, t) |= rational_reflection_self (X, R1) &
R1 ≥ MIN_LEVEL_SELF &
state(γ, t) |= rational_reflection_support (X, K1) &
K1≥ MIN_LEVEL_SUPPORT & state(γ, t) |= cog_vulnerability (X,V1) & V1 > 0] ⇒
∃t':TIME > t:TIME [state(γ, t') |= cog_vulnerability (X,V2) & V1 < V2]

In some simulation traces, a condition was added to the antecedent of the formal property, namely t=200 so the property only checked at the given time step. In general, this property can be used to verify future condition of an individual if the individual capable to infer positive (rational) interpretations of experienced events throughout time.

**VP5: Monotonic Increase of Cognitive Vulnerability for Individual without Good Skills and Experiencing Prolonged Stressors**

When an individual is incapable to perform RBET, then the individual will prone to develop further cognitive vulnerability in future.

VP2 ≡ ∀γ:TRACE, t, t':TIME, D1,D2,F1,F2:REAL, X:AGENT
[state(γ, t) |= stressors (X, D1) &
state(γ, t') |= stressors (X, D2) &
state(γ, t) |= cog_vulnerability (X,F1) &
state(γ, t')|= cog_vulnerability (X,F2) & t' > t &
D2 ≥ D1] ⇒ F2 ≥ F1

By checking property VP5, one can verify whether any individual (without good skills in RBET) increase monotonically in his/her cognitive vulnerability after experiencing prolonged stressors.

**VP6: Monotonic Decrease of Cognitive Vulnerability for Any Individual When Stressors are Reduced**

When an individual is experiencing lesser stressors throughout time, then the individual will reduce the level of cognitive vulnerability in future.

VP3 ≡ ∀γ:TRACE, t, t':TIME, D1,D2,F1,F2:REAL, X:AGENT
[state(γ, t) |= stressors (X, D1) &
state(γ, t') |= stressors (X, D2) &
state(γ, t) |= cog_vulnerability (X,F1) &
state(γ, t')|= cog_vulnerability (X,F2) & t' > t &
D2 ≤ D1] ⇒ F2 ≤ F1

Property VP6 can be used to verify individual's condition when negative events (stressors) are decreasing throughout time.

## 11. Conclusion

Depression is a serious mood disorder that influences the life of the patient enormously. Unfortunately, the disease has a high rate of relapse. The occurrence of depression and the rate of relapse are probably related to the cognitive vulnerability of the patients. In this article, the assumed role of negative cognitive content in depression is explained. Based on this, an agent-model is presented that describes the temporal relation between personal characteristics, negative life events and social support. This model is used in a small simulation to investigate the effect of different types of support on different persons that undergo similar life events. The mathematical analysis of the model and the verification of expected behaviour of the modelled agents in the simulation traces give some evidence for the appropriateness of the model. This model is used as the basic component of an intelligent agent application aimed at supporting people to prevent the onset of a depression. The application uses the model to analyze patients and detect risk situations.

When such situations are detected, an intervention is taking place following the principles of Rational Emotive Behavioural Therapy (based on changing the underlying thoughts). A software simulation has been implemented to study the effect of the application. In these simulations, three cases are compared: a not cognitive-vulnerable person, a person that responds to REBT therapy, and a person that does not respond to the therapy. Finally, using several generated traces, the ambient agent model has been verified using a number of important properties in the literature. In the future, we would like to extent the model with the effect of negative thoughts and a bad mood on the willingness to provide support. Together with the existing elements of the model, this would allow for a multi-agent simulation of a larger community, in which different persons interact with each other by giving and receiving support. Such analysis would make it possible to investigate the consequences of depressive persons in a small community.

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## References

1. Abramson, L.Y., Alloy, L.B., Hogan, M.E., Whitehouse, W.G., Donovan, P., Rose, D.T., Panzarella, C., Raniere, D. (1999). Cognitive vulnerability to depression: Theory and evidence. Journal of Cognitive Psychotherapy, 13, 5-20.
2. Abramson, L.Y., Metalsky, G.I., Alloy, L.B. (1989). Hopelessness depression: a theory-based subtype of depression, Psychol. Rev. 96, pp. 358–372.
3. Alloy, L. B., Abramson, L. Y., Gibb, B. E., Crossfield, A. G., Pieracci, A. M., Spasojevic, J., Steinberg, J. A. (2004). Developmental antecedents of cognitive vulnerability to depression: Review of findings from the cognitive vulnerability to depression project. Journal of Cognitive Psychotherapy, 18(2), 115-133.
4. Alloy, L. B., Abramson, L. Y., Tashman, N. A., Berrebbi, D. S., Hogan, M. E., Whitehouse, W. G., et al. (2001). Developmental origins of cognitive vulnerability to depression: Parenting, cognitive, and inferential feedback styles of the parents of individuals at high and low cognitive risk for depression. Cognitive Therapy and Research, 25(4), 397–423.
5. Aziz, A.A., Klein, M.C.A., Treur, J. (2009). An Agent Model of Temporal Dynamics in Relapse and Recurrence in Depression. In: Ali, M., Chen, S.M., Chien, B.C., Hong, T.P. (eds.), IEA-AIE 2009. LNAI, Springer Verlag.

6. Aziz, A.A., Klein, M.C.A. , and Treur, J. (2010) An Integrative Ambient Agent Model for Unipolar Depression Relapse Prevention, Journal Of Ambient Intelligence And Smart Environments, Vol. 2, pp.5-20.
7. Aziz, A.A., Treur, J. (2009) Modelling Dynamics of Social Support Networks for Mutual Support in Coping with Stress. In: Nguyen, N.T., Katarzyniak, R., Janiak, A. (eds.). Challenges in Computational Collective Intelligence, ICCCI' *09*, Studies in Computational Intelligence, pp. 167-179 Springer Verlag.
8. Beck, A.T. (1987) Cognitive Models of Depression, Journal of Cognitive Psychotherapy 1, pp. 5–37.
9. Bolger, N., and Amarel, D. (2007) Effects of social support visibility on adjustment to stress: experimental evidence. Journal of Personality and Social Psychology, 92, pp 458-475.
10. Bosse, T., Jonker, C.M., Meij, L. van der, Sharpanskykh, A., Treur, J. (2009) Specification and Verification of Dynamics in Agent Models. International Journal of Cooperative Information Systems, vol. 18, pp. 167 – 193.
11. Bosse, T., Jonker, C.M., Meij, L. van der, Treur, J. (2007) A Language and Environment for Analysis of Dynamics by Simulation. International Journal of Artificial Intelligence Tools, vol. 16, pp. 435-464.
12. Bosse, T., Hoogendoorn, M., Klein, M., and Treur, J. (2009) A Generic Agent Architecture for Human-Aware Ambient Computing. In: Mangina, E., Carbo, J., and Molina, J.M. (eds.), Agent-Based Ubiquitous Computing. Series on Ambient and Pervasive Intelligence, vol. 1. World Scientific Publishers: Atlantis Press, pp. 35-62.
13. Both, F., Hoogendoorn, M., Klein, M.C.A., and Treur, J. (2009) Design and Analysis of an Ambient Intelligent System Supporting Depression Therapy. In: Luis Azevedo and Ana Rita Londral (Eds), Proceedings of the Second International Conference on Health Informatics, HEALTHINF'09. INSTICC Press, pp. 142-148.
14. Brilman, E.I., and Ormel, J. (2001) Life Events, Difficulties, and Onset of Depressive Episodes in Later Life, Psychological Medicine 31.
15. Coyne, J.C. (1990). Interpersonal process in depression. In: G.I. Keitner, Editor, Depression and families: Impact and treatment, American Psychiatric Press, Washington, DC , pp. 31–53.
16. Crossfield, A.G., Alloy, L.B., Gibb, B.E. (2002) and Abramson, L.Y. The Development of Depressogenic Cognitive Styles: The Role of Negative Childhood Life Events And Parental Inferential Feedback. Journal of Cognitive Psychotherapy, 16(4), pp. 487–502.
17. DeFronzo R., Panzarella, C., Butler, A.C. (2001) Attachment, support seeking, and adaptive feedback: Implications for psychological health, Cognitive and Behavioral Practice 8, pp. 48–52.
18. Dobkin, R.D., Panzarella, C.J., Alloy, L.B, and Cascardi, M. (2004) Adaptive Inferential Feedback, Depressogenic Inferences, And Depressed Mood: A Laboratory Study of The Expanded Hopelessness Theory of Depression, Cognitive Therapy And Research, pp. 487–509.
19. Ellis, A. (2000) Can rational emotive behavior therapy (REBT) be effectively used with people who have devout beliefs in God and religion? Professional Psychology: Research and Practice, 31(1), pp. 29-33.
20. Ellis, A. (2003) Early Theories And Practices Of Rational Emotive Behaviour Theory And How They Have Been Augmented And Revised During The Last Three Decades. Journal of Rational-Emotive & Cognitive-Behaviour Therapy, 21(3/4).
21. Fairclough S.H., (2009) Fundamentals of physiological computing, Interacting with computers. 21 (1-2) , pp.133–145.
22. Heller, K., Rook, K.S. (1997). Distinguishing the theoretical functions of social ties: Implications for support interventions. In: S. Duck, Editor, Handbook of personal rela-

tionships: Theory, research, and interventions, John Wiley and Sons, Chichester, England, pp. 649–670.

23. Lyons, L. C., and Woods, P. J. (1991). The efficacy of rational-emotive therapy: A quantitative review of the outcome research. Clinical Psychology Review, 11, 357-369.
24. Nolen-Hoeksema, S. (2000). Ruminative responses predict depressive disorders. Journal of Abnormal Psychology, 109, pp.504-511.
25. Panzarella, C., Alloy, L. B. (1995). Social support, hopelessness, and depression: An expanded hopelessness model. In L.B. Alloy (Chair), The hopelessness theory of depression: New developments in theory and research. 29th Annual Convention of the Association for Advancement of Behaviour Therapy, Washington, DC.
26. Panzarella, C., Alloy, L.B., Whitehouse, W.G. (2006). Expanded hopelessness theory of depression: On the mechanisms by which social support protects against depression, Cognitive Therapy and Research 30 (3), pp. 307–33.
27. Picard, R.W., Vyzas, E., and Healey, J. (2001) Towards machine emotional intelligence: analysis of affective physiological state, IEEE Transactions on Pattern Analysis and Machine Intelligence. Vol.23 (10).
28. Roberts, J.E, Gotlib I.H (1997), Social support and personality in depression: Implications from quantitative genetics. In: R. Pierce, B. Lakey, I.G. Sarason and B.R. Sarason, Editors, *Sourcebook of social support and personality*, Plenum Press, New York, pp. 187–214.
29. Robinson, M. S., Alloy, L. B. (2003). Negative cognitive styles and stress-reactive rumination interact to predict depression: A prospective study. Cognitive Therapy & Research, 27(3), 275-292.
30. Segal, V.Z., Pearson, L.J., Thase, M.E (2003). Challenges in Preventing Relapse in Major Depression: Report of a National Institute of Mental Health Workshop on State of the Science of Relapse Prevention in Major Depression. *Journal of Affective Disorders* 77, 97-108.
31. Spasojevic, J. and Alloy, L.B. (2001) Rumination as A Common Mechanism Relating Depressive Risk Factors To Depression. Emotion, 1(1), pp.25-37.
32. Treur, J. (2008) On Human Aspects in Ambient Intelligence. In: Proceedings of the First International Workshop on Human Aspects in Ambient Intelligence. Published in: M. Mühlhäuser, A. Ferscha, and E. Aitenbichler (eds.), Constructing Ambient Intelligence: AmI-07 Workshops Proceedings. Communications in Computer and Information Science (CCIS), vol. 11, Springer Verlag, pp. 262-267.
33. Zhai, J. and Barreto, A.B. (2005) Instrumentation for automatic monitoring of affective state in human-computer interaction, In 18th International Florida Artificial Intelligence Research Society Conference, pp. 207-212.