SIMULATING THE EFFECT OF THERAPIES AND TRAUMAS ON EMOTION REGULATION

Matthijs Pontier

Vrije Universiteit, Department of Artificial Intelligence
De Boelelaan 1081, 1081 HV Amsterdam, The Netherlands

Center for Advanced Media Research Amsterdam
Buitenveldertselaan 3, 1082 VA Amsterdam, The Netherlands

E-Mail: mpr210@few.vu.nl

KEYWORD

Agent-Based Modelling, Emotion Regulation

ABSTRACT

Previous research suggests that therapies can help people to regulate their emotions, and on the other hand, traumas can cause impaired emotion regulation. This paper introduces a computational model for simulating the effects of events like traumas or therapies on emotion regulation. This model is an extension of an existing computational model of emotion regulation (Bosse et al. 2007c). A number of simulation experiments has been performed and evaluated.

INTRODUCTION

In science, emotions were historically seen as neural activation states without a function (Hebb 1949). However, recent research indicates that emotions are functional. Emotions have a facilitating function in decision making (Oatley and Johnson-Laird 1987), prepare a person for rapid motor responses (Frijda 1986), and provide information regarding the ongoing match between organism and environment (Schwarz and Clore 1983). Emotions also have a social function. They provide us information about others' behavioural intentions, and script our social behaviour (Gross 1998).

In the past two decades, psychological research has started to focus more on *emotion regulation* (e.g., Gross, 1998; 1999; 2001; 2002; Thompson 1994), i.e., the process humans undertake to increase, maintain or decrease their emotional response.

Gross has described an informal process model for emotion regulation (Gross 2001). Based on this model, Bosse et al. (2007b; 2007c) have introduced a computational model of emotion regulation. In this model, the personal flexibility in changing emotion regulation behaviour, based on meta-cognition about the emotion regulation process, is fixed. In real life, however, this personal tendency to adjust behaviour can be changed by certain events. For instance, if someone has a very low tendency to change his behaviour in order to regulate his emotions, a therapy could help that person to change this tendency, and help him learn to adapt this regulation of emotions in a more flexible manner. Previous research suggests that therapies can help people to regulate their emotions. For instance, Beck and Fernandez describe, based on 50 studies, that people who were treated with a cognitive behavioural therapy as an approach for anger management were better off than 76% of untreated subjects, in terms of anger reduction (Beck and Fernandez 1998). In addition, an article by Burns et al. suggests that a structured anger management training programme is useful for forensic inpatients with learning disability (Burns et al. 2003). Finally, Deschner and McNeil describe an experiment, in which families that experienced violence, followed anger control training. After the training, 85% of the families were free of further violence and remained so, according to an independent survey completed 6-8 months later (Deschner and McNeal 1986). On the other hand, an event like a trauma could decrease the tendency to change one's behaviour in order to regulate his emotions significantly. Schore describes that an early trauma can cause impaired affect regulation (Schore 2001).

This article presents an extension of the emotion regulation model by Bosse et al. (2007c) that makes it able to simulate events that influence the emotion regulation process, like traumas or therapies. Simulation experiments have been performed to test whether events with a positive effect on the personal tendency to change behaviour in favour of emotion regulation, like therapies, facilitate emotion regulation, and events with a negative effect on the tendency to change behaviour, like traumas, impair emotion regulation.

This model could be used for several purposes. For example, from a Cognitive Science perspective, a model that simulates emotion regulation could give insight in the process of emotion regulation. An advanced model could also be helpful to make predictions about emotions, about behaviour that is a consequence of emotions, and about how to influence certain behaviours with, e.g., an anger management therapy. This could be useful in for instance work with forensic inpatients. In addition, a model for emotion regulation can be used in the field of Artificial Intelligence, see e.g. (Bates 1994). For example, in the virtual reality domain it can be used to let virtual agents show human-like emotion regulation behaviour. Similarly, in the gaming industry, there is much interest in manners to let game characters emotionally behave like humans.

Proceedings 22nd European Conference on Modelling and Simulation ©ECMS Loucas S. Louca, Yiorgos Chrysanthou, Zuzana Oplatková, Khalid Al-Begain (Editors)
ISBN: 978-0-9553018-5-8 / ISBN: 978-0-9553018-6-5 (CD)

EMOTION REGULATION

Gross has informally described a process model of emotion regulation (Gross 2001). According to this model, people can use strategies to influence their level of emotion at different time points. Gross mainly differentiates between *antecedent-focused strategies* and *response-focused strategies*. Antecedent-focused strategies are applied before response tendencies have become fully activated. These are strategies to prevent a person from becoming too emotional, or too little emotional. Response-focused strategies are applied when an emotion is already under way, and response tendencies have been generated. These strategies focus on the way emotions are expressed, and are mainly driven by social factors.

In his model, Gross distinguishes five different emotion regulation strategies, which can be applied at five different time points. Four of them are antecedent-focused strategies: situation selection, situation modification, attentional deployment and cognitive change. The fifth one, response modulation, is a response-focused strategy. All strategies are shown in Figure 1.

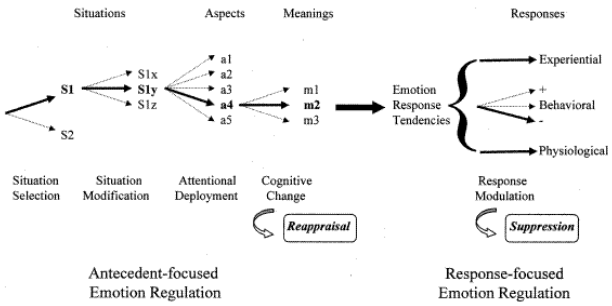

Figure 1: Process Model of Emotion Regulation by Gross (2001)

The first emotion regulation strategy in the model is *situation selection*. When this strategy is applied, a person chooses to be in a situation that matches the emotional level he wants to experience for a certain emotion. For example, a person could refuse an invitation to a party, because he is in a conflict with someone who is going to that party, and he would feel angry when seeing him. This is an example of down-regulating one's emotion. Deciding to make a bungee jump is an example in which the level of emotion is raised.

The second emotion regulation strategy in the model is *situation modification*. When this strategy is applied, a person modifies a situation so that it better fits to a person's optimal level of emotion. For instance, when a person is watching a television interview with a very annoying political leader, he might zap to another channel.

The third emotion regulation strategy is *attentional deployment*. This strategy refers to shifting your attention to a certain aspect. An example of attentional deployment is when a person is watching an important soccer game that ends in a penalty shoot-out, and he chooses to put his hands before his eyes, instead of watching the final penalty, because it is too exciting.

The fourth emotion regulation strategy is *cognitive change*. This is a strategy in which one selects a cognitive meaning to attach to an event. An example of cognitive change is when a team loses a soccer match, and a player blames this on his teammates, instead of on his own play.

The fifth emotion regulation strategy, *response modulation*, is a response-focused strategy, and is applied after the emotion response tendencies have been generated. When a person applies response modulation, it tries to influence the process of response tendencies becoming a wanted behavioural response. An example of response modulation is hiding that you are nervous when giving a presentation.

Cognitive-Behavioral Therapies have the purpose to facilitate beneficial use of emotion regulation strategies. They focus on cognitive aspects, as well as behavioural aspects. The behavioural part focuses on replacing counterproductive emotional driven behaviours with alternatives. This has a facilitating effect on beneficial use of situation selection, situation modification, and attentional deployment. The cognitive part focuses on substituting irrational negative appraisals for evidence-based appraisals. This has a facilitating effect on beneficial use of cognitive change (Campbell-Sills & Barlow 2006).

MODELLING APPROACH

Modelling the various aspects involved in emotion regulation in an integrated manner poses some challenges. On the one hand, qualitative aspects have to be addressed, such as decisions to regulate one's emotion (e.g., by selecting a different situation). On the other hand, quantitative aspects have to be addressed, such as levels of emotional response. The modelling approach based on the modelling language LEADSTO (Bosse et al. 2007a) fulfils these needs. It integrates qualitative, logical aspects such as used in approaches based on temporal logic (e.g., Barringer et al. 1996) with quantitative, numerical aspects such as used in Dynamical Systems Theory (e.g., Ashby 1960; Port and Gelder 1995).

In LEADSTO, direct temporal dependencies between state properties in two successive states are modelled by executable dynamic properties defined as follows. Let a and b be state properties of the form "conjunction of literals" (where a literal is an atom or the negation of an atom), and e, f, g, h non-negative real numbers. Then in the *leads to* language $a \twoheadrightarrow_{e, f, g, h} b$, means:

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

Here, atomic state properties can have a qualitative, logical format, such as an expression desire(d), expressing that desire d occurs, or a quantitative, numerical format such as has_value(x, v) expressing that variable x has value v.

OVERVIEW OF THE SIMULATION MODEL

This model is an extension of a previous model (Bosse et al. 2007c). This section gives an overview of this model. For convenience, the model concentrates on one specific type of emotion. In principle, this can be any emotion that is considered to be a basic human emotion, e.g., sadness, happiness, or anger (Ekman et al. 1972).

In order to be able to formalise Gross' model, for any given type of emotion a number of variables have been introduced. We have chosen to express the *emotion response level* ERL in a real number, in the domain [0, 2]. A higher emotion response level means a person feels more emotion. Humans are always aiming for an optimal level of emotion. The location of this optimum depends interpersonally. For instance, there are people who enjoy extreme sports, or roller coasters, while others prefer a more quiet kind of recreation. The optimal level of emotion also depends on the type of emotion. Most people have a relatively high optimal level of emotion for happiness, while they have a lower optimal level of emotion for fear. In the model, there is a fixed optimal level of emotion ERL_{norm}, also expressed in a real number in the domain [0, 2].

In the model of Gross, five different strategies for five different elements can influence the emotion response level. Because in the experiments of Gross (Gross 2001) the strategy response modulation had no effect on the emotion experience, it is not considered in this paper. However, the model is constructed in such a way that the set of strategies can easily be adapted. The four remaining strategies that are considered and their corresponding elements are shown in Table 1.

Table 1: The Four Considered Emotion Regulation Strategies and their Corresponding Elements

Strategy	**Element**
Situation selection	situation
Situation modification	subsituation
Attentional deployment	aspect
Cognitive change	meaning

In the real world, a person can always choose between a limited number of options for each strategy. Due to simplification, this model assumes that at every time point, for each element, a person makes a certain choice, which has a certain *emotional value* v_n attached. In the computational model, we also express the emotional values of the four different elements in real numbers in the domain [0, 2]. This emotional value contributes to the emotion response level via an element-specific weight factor w_n, thereby taking into account a persistency factor β, indicating the degree of persistence or slowness of adjusting the emotion response level when new emotional values are obtained. Someone whose emotions can change very rapidly (e.g., who stops being angry in a few seconds) will have a very low β.

The regulation process compares the actual emotion response level ERL to the emotion response level aimed at ERL_{norm}. The difference d between the two is the basis for adjustment of the choices made for each of the elements n; based on these adjusted choices, each element n will have an adjusted emotional value v_n. The strength of such an adjustment is expressed by a *modification factor* α_n, which represents the flexibility to change one's emotional value for a certain element.

In order to obtain a model that can adapt itself to various circumstances, the modification factors α_n have been made adaptable. The flexibility to choose different emotional values v_n can be adapted to an assessment of the emotion regulation process: a sort of reflection or meta-cognition about the emotion regulation process based on the history of differences d. The *adaptation factor* γ_n mediating in this adaptation process represents the personal flexibility to adjust the emotion regulation behaviour based on such an assessment. It takes some effort to change behaviour in favour of emotion regulation. This effort, or the costs of adjusting the modification factor for element n, is represented by c_n.

The model is shown in a qualitative manner in the graph depicted in Figure 2. The variables above the dashed line are added in this paper, and will be explained in the next section. Note that the model contains two cycles. One is the basic emotion regulation cycle from the v_n to ERL via d back to the v_n. The other one is the adaptation cycle from the α_n to the basic regulation cycle and back (via v_n , ERL and d back to α_n).

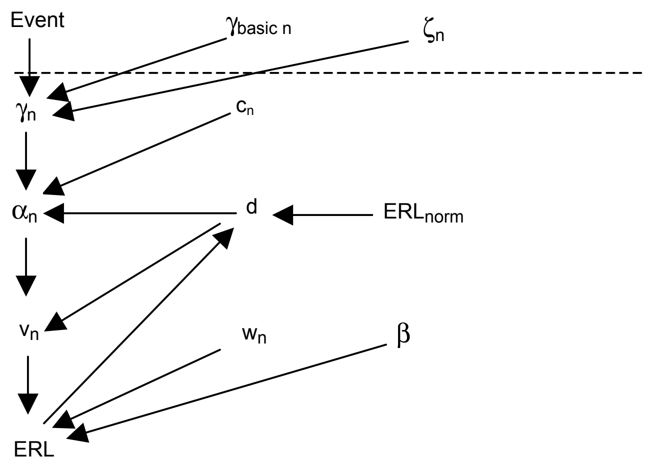

Figure 2: Dependencies between the Variables.

The processes modelled here are in real life continuous. Since simulation needs some form of discretisation, this model works with a fixed step size s that can be taken any size as desired.

ADDING THE POSSIBILITY TO SIMULATE EVENTS LIKE TRAUMA'S AND THERAPIES

In order to simulate events that can change the personal tendency to adjust behaviour in favour of emotion regulation γ, we have chosen to express these events in real numbers in the domain [-1, 1]. If an event has a high value, for instance a successful therapy, it will lead to a higher tendency to adjust behaviour in favour of emotion regulation. If the value gets closer to 0, it will have a smaller effect, and when it reaches 0 it will have no effect at all. An event with a negative value, for instance a trauma, will result in a lower tendency to adjust emotion regulation behaviour. The following formula is used to let events influence the tendency to adjust behaviour in favour of emotion regulation:

$$\Delta\gamma_n = \zeta_n * \text{Event} / (1 + (\gamma_n - \gamma_{\text{basic } n}) * \text{Event}) * \Delta t$$
$$\text{new\_}\gamma_n = \text{old\_}\gamma_n + \Delta\gamma_n$$

These formulas are represented by the following LEADSTO properties:

LP7 (Keep old gamma)
gamma(gamma)
and not change_gamma
$\twoheadrightarrow_{0,\,0,\,s,\,s}$ gamma(gamma)

LP8 (Change gamma)
experience(exp)
and gamma(gamma)
$\twoheadrightarrow_{0,\,0,\,s,\,s}$ gamma(gamma + zeta * exp / (1 + (gamma-gamma_basic) * exp))

In these formulas, new_γ_n is the new personal tendency γ_n, and old_γ_n is the old personal tendency γ_n. $\Delta\gamma_n$ is the change of γ_n. The new γ_n is derived by adding $\Delta\gamma_n$ to the old γ_n. The variable 'Δt' is the time step, which is taken 1 in this paper. ζ_n is a variable that determines the speed with which the personal tendencies are adjusted by events. In simulation experiments, a ζ_n in the range 0.10 – 0.20 seemed to be most realistic. Event is the value that is attributed to a particular event that is simulated in the model. $\gamma_{\text{basic } n}$ is a person's basic personal tendency to change its behaviour in favour of emotion regulation. Assumed is that a person is born with a basic personal tendency to change behaviour in favour of emotion regulation, and this personal tendency can be changed by events. However, when the γ_n deviates more from $\gamma_{\text{basic } n}$, and an event influences γ_n to deviate even more from $\gamma_{\text{basic } n}$, γ_n will be changed less than when it is influenced by an event with the same strength in the different direction. So for instance, when a person has a very low $\gamma_{\text{basic } n}$, but a series of events made the γ_n rise to a much higher level, an Event with the value 0.5 will make the γ_n raise only a little bit more, while an Event with the value -0.5 will make the γ_n decrease significantly. In other words, events can change a person's personal tendency, but it gets harder when the personal tendency has already changed much. Table 2 shows a summary of all the treated variables. The variables depend on each other as shown in a qualitative manner in the graph depicted in Figure 2.

Table 2: Summary of All Variables

Variable	Meaning
ERL	Level of emotion
ERL_{norm}	Optimal level of emotion
d	Difference between ERL and ERL_{norm}
β	Slowness of adjustment ERL
w_n	Weight of element n in adjusting the ERL
v_n	Chosen emotional value for element n
α_n	Modification factor that represents the 'willingness' to change the emotional value of element n
γ_n	Personal tendency to adjust the emotional value of element n much or little
$\gamma_{\text{basic } n}$	Basic personal tendency to adjust the emotional value of element n much or little
c_n	Costs of adjusting emotional value v_n
Event	Value of an event that reflects the impact it has on personal tendency γ
ζ_n	Variable that determines the speed with which events influence personal tendencies
Δt	Time step

SIMULATION EXPERIMENTS

A number of experiments have been performed on an agent, to test whether the model can simulate the effects of events like traumas or therapies on emotion regulation. The variables that were used in the experiments are summarized in Table 3. The values of the fixed variables and the initial values of the remaining variables are shown.

Table 3: A Summary of the Variables that Have the Same Value for All Experiments

Variable	Value	Fixed / Initial
ERL_{norm}	0.5	Fixed
β	0.7	Fixed
ERL	1.8	Initial
v_1-v_4	1.8	Initial
w_1	0.35	Fixed
w_2	0.30	Fixed
w_3	0.20	Fixed
α_1 - α_4	0.01	Initial
c_1	0.7	Fixed
c_2	0.4	Fixed
c_3	0.4	Fixed
c_4	0.6	Fixed
γ_1 - γ_4	0.01	Initial
$\gamma_{\text{basic } 1}$ - $\gamma_{\text{basic } 4}$	0.05	Fixed
ζ_1 - ζ_4	0.15	Fixed

The experiments in this paper simulate the behaviour of an individual. The simulated emotion is anger, and the agent's optimal level of anger is 0.5. The agent starts with a very high emotion response level of 1.8, and very high emotional values, all set to the same level of 1.8. So at the start of the simulation, our agent is very angry, and is in a situation that keeps him angry. The weights, and the costs attached to the various elements are set to the same values as in the previous model (Bosse et al. 2007c). The γ_n's, which represent the personal tendency to change behaviour in favour of emotion regulation, are initially set to 0.01, which is a very low value. The value for all $\gamma_{basic\ n}$'s is set to 0.05. This is somewhat lower than average, which means that by nature the agent has a relatively low personal tendency to change behaviour in favour of emotion regulation. The initial γ_n is even lower, which means that before the start of the simulation, the agent has had some experiences, for example a trauma, which decreased its personal tendency to change behaviour in favour of emotion regulation. The ζ_n are all set to 0.15. Experiments showed that this is a normal value. In the experiments in this chapter, the manipulated variables are the events that influence the personal tendency to change behaviour in favour of emotion regulation.

Experiment 1: The effect of a successful anger management therapy

In this simulation, we let our agent experience an event that will increase its personal tendency to change behaviour in favour of emotion regulation very much: a successful cognitive-behavioural anger management therapy. This event takes place at time point 40, and has the value of 0.9 in the domain [-1, 1]. The results of this simulation can be seen in Figure 3. Because all emotional values and modification factors show similar behaviour, and the only difference is made by the costs, only the graphs of the element with the highest costs, situation, and of one of the elements with the lowest costs, subsituation, are shown.

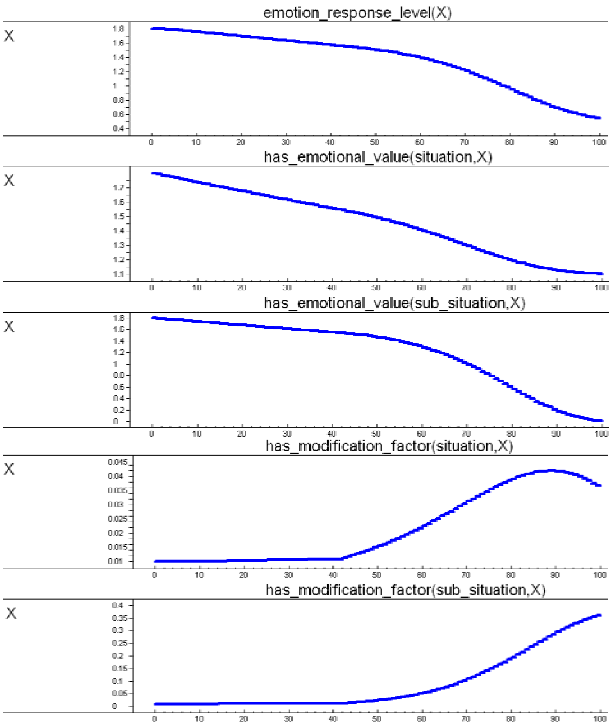

Figure 3: Simulation of the Emotion Response Level, the Emotional Values and the Modification Factors in Experiment 1

As can be seen in Figure 3, the emotion response level first decreases very slowly. Later in the simulation, after the therapy has taken place, the emotion response level starts to descend more quickly, and at the end of the simulation the optimal level of emotion is reached. So at the beginning of the simulation, the agent is not able to let its level of anger decrease to its optimal level, but at the end of the simulation it is. This can also be seen in the simulations of the emotional values. First these values decrease very slowly, and later in the simulation they decrease much quicker. This is the clearest in the emotional values of elements with lower costs, such as subsituation. These emotional values decrease much more than the emotional values of elements with higher costs. At the end of the simulation, the emotional values of elements with lower costs have almost reached 0, while the emotional value of situation selection, with higher costs, has decreased only until 1.1.

The modification factors α_n increase very slowly at the beginning of the simulation, and start to increase more quickly after the therapy has taken place. The modification factors of elements with lower costs increase much quicker than the elements with higher costs. At the end of the simulation, the modification factors of elements with lower costs have increased until 0.37, while the modification factor of situation selection, with higher costs, has increased only until 0.042, and has started to decrease again.

It makes sense that the modification factors increase very slowly at first, and start to increase quicker at a later time point in the simulation. At time point 40, an event takes place, which makes the personal tendency to change behaviour in favour of emotion regulation, represented by the γ_n, rise from 0.01 to 0.15. These γ_n have a direct effect on the modification factors, as can be seen in Figure 2. Especially in the simulation of the modification factor of situation selection, the impact this has on the modification factors can be seen. A few steps after time point 40, the modification factor starts to increase much quicker. So after the anger management therapy, it immediately starts to increase its willingness to change its behaviour in favour of emotion regulation.

The impact this has on the emotional values can be seen very clearly. After time point 40, the emotional values start to decrease much quicker. After a while, the emotion response value has decreased enough to make the emotional value for situation selection decrease more slowly again. So our agent is not able to reach its optimal level of emotion by choosing different situations, cognitive meanings, etc. in the first part of the simulation, but after the anger management therapy at time point 40, it starts to change its behaviour, and at the end of the simulation it has reached its optimal level of emotion, and is able to keep it stable.

Experiment 2: The effect of a series of events

In this simulation, we let our agent experience various events that change its personal tendency to change behaviour in favour of emotion regulation. First, at time point 20, the agent experiences an event that is just as ‘strong’ as the event at time point 40 in experiment 1. So the same agent follows the same cognitive-behavioural anger management therapy with the same amount of success as in experiment 1, only now it already takes place at time point 20. At time point 40, the agent experiences an event that is just as strong as the event at time point 20, but now in the opposite direction, so that it will decrease its personal tendency to change behaviour in favour of emotion regulation. In real life, this event could be for instance a severe traumatic experience. At time point 60, the agent experiences a positive event with the strength 0.4, for instance a therapy that helps it deal with the traumatic event he experienced at time point 40. Finally, at time point 80, the agent experiences a negative event with the strength of 0.3.

Table 4: A Summary of the Events in Experiment 2

Event at time point 20	0.9
Event at time point 40	-0.9
Event at time point 60	0.4
Event at time point 80	-0.3

The results of this simulation can be seen in Figure 4. Again, because all emotional values and modification factors show similar behaviour, and the only difference is made by the costs, only the graphs of the element with the highest costs, situation, and of one of the elements with the lowest costs, subsituation, are shown.

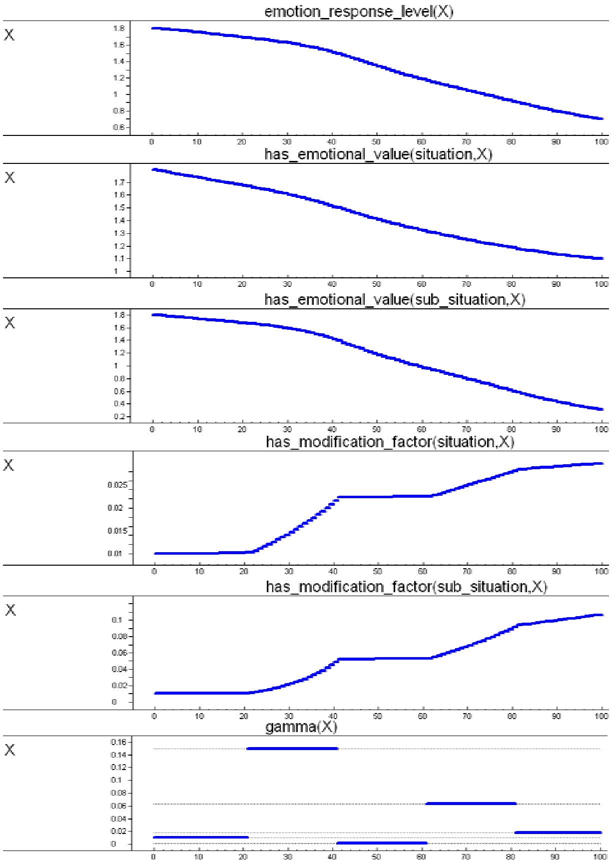

Figure 4: Simulation of the Emotion Response Level, the Emotional Values, the Modification Factors, and the γ_n in Experiment 2

As can be seen in Figure 4, the emotion response level decreases very slowly at the start of the simulation. After the anger management at time point 20, which makes the γ_n rise to 0.15, the emotion response level starts to decrease somewhat quicker. Because the traumatic event at time point 40 makes the γ_n decrease to an even lower level than it was at the beginning of the simulation, this decreasing trend does not proceed the way it did in experiment 1. The effects of the less powerful events at time point 60 and 80 can clearly be seen by the kinks in the graphs of the modification factors, but the effects on the emotional values and the emotion response level are less clear. It can clearly be seen that the less powerful events have a smaller impact on the γ_n.

DISCUSSION

In this paper, a computational model for simulating the effects of events like traumas or therapies on emotion regulation has been described. This model is an extension of the model by Bosse et al. (2007b; 2007c), and was inspired by the process model of emotion regulation as informally described by Gross (Gross 2001).

The simulation experiments have demonstrated that the model can simulate the effects of events that influence the personal tendency to change behaviour in favour of emotion regulation, like trauma's, or therapies. In experiment 1, the agent has at first a low tendency to change its behaviour, and is because of this low tendency not able to reach its optimal level of emotion. After an anger management therapy, its personal tendency to change behaviour in favour of emotion-regulation has increased, and the agent is able to regulate its emotions, and reach its optimal level of emotion. In experiment 2, a series of events influence the agent’s emotion regulation. In this experiment, the relatively ‘stronger’ events have a bigger impact on the emotion regulation process. These results are consistent with the literature (e.g., Beck and Fernandez 1998; Deschner and McNeal 1986). Validation involving extensive comparison with detailed empirical data is left for future work.

Possible improvements to this model could be introducing decay for the γ_n, which represent the personal tendency to change behaviour in favour of emotion regulation. This way, the γ_n would slowly return to the value of $\gamma_{basic\ n}$ if no events occur that influence the γ_n. Also, in the formulas that are used to calculate the new emotional values, the emotion response level could be modified by a random factor. The size of this random factor could be changed in order to simulate emotion regulation in people that are not able to recognize their level of emotion very well. Furthermore, in this model, Gross' notion of response modulation is not considered, and thus has no effect on the emotion regulation at all. It could be the case that response modulation at the long term, for instance the suppression of a traumatic experience, could have an effect on emotion regulation. The model could be changed in order to make it able to simulate this. Finally, in the current model, a trauma cannot cause a relapse in the emotion regulation process. It can only slow down the process. The model could be changed so that a trauma would not only influence the personal tendency to change behaviour in favour of emotion regulation, but also the willingness to change behaviour in favour of emotion regulation, and the chosen emotional values.

REFERENCES

Aarts, E., Harwig, R., and Schuurmans, M. 2001. "Ambient Intelligence." In *The Invisible Future: The Seamless Integration of Technology into Everyday Life*, McGraw-Hill, 2001.

Ashby, R. 1960. *Design for a Brain*. Second Edition. Chapman &Hall, London. First edition 1952.

Barringer, H., Fisher, M., Gabbay, D., Owens, R., and Reynolds, M. 1996. *The Imperative Future: Principles of Executable Temporal Logic*, John Wiley & Sons, 1996.

Bates, J. 1994. "The role of emotion in believable agents." *Communications of the ACM*, Vol. 37, No. 7, pp. 122-125.

Beck, R., and Fernandez, E. 1998. "Cognitive-Behavioral Therapy in the Treatment of Anger: A Meta-Analysis." *Cognitive Therapy and Research*, 1998, Vol. 22, No. 1, pp. 63-74.

Bosse, T., Jonker, C. M., Meij, L. van der, Sharpanskykh, A., and Treur, J. 2006. "Specification and Verification of Dynamics in Cognitive Agent Models." In *Proceedings of the Sixth International Conference on Intelligent Agent Technology, IAT'06*. IEEE Computer Society Press, 2006, pp. 247-254.

Bosse, T., Jonker, C.M., Meij, L. van der, and Treur, J. 2007a. "A Language and Environment for Analysis of Dynamics by Simulation." *International Journal of Artificial Intelligence Tools*. Vol. 16, 3, 2007, pp. 435-464.

Bosse, T., Pontier, M., and Treur, J. 2007b. "A Computational Model for Adaptive Emotion Regulation." In Lin, T.Y., Bradshaw, J.M., Klusch, M., Zhang, C., Broder, A., and Ho, H. (Eds.) *Proceedings of the Sixth IEEE/WIC/ACM International Conference on Intelligent Agent Technology, IAT'07*. IEEE Computer Society Press, 2007, pp. 289-293.

Bosse, T., Pontier, M., and Treur, J. 2007c. "A Dynamical System Modelling Approach to Gross´ Model of Emotion Regulation." In Lewis, R.L., Polk, T.A., and Laird, J.E. (Eds.) *Proceedings of the 8th International Conference on Cognitive Modeling, ICCM'07*. Taylor and Francis, 2007, pp. 187-192.

Burns, M., Bird, D., Leach, C., and Higgins, K. 2003. "Anger management training: the effects of a structured programme on the self-reported anger experience of forensic inpatients with learning disability." *Journal of Psychiatric and Mental Health Nursing*, 2003, Vol. 10, pp. 569–577.

Campbell-Sills, L. and Barlow, D. H. 2006. "Incorporating Emotion Regulation into Conceptualizations and Treatments of Anxiety and Mood Disorders" In Gross, J. J. (Ed.) *Handbook of Emotion Regulation*, Guilford press, New York

Deschner, J. P., and McNeil, J. S. 1986. "Results of Anger Control Training for Battering Couples." *Journal of Family Violence*, 1986, Vol. 1, No. 2, pp. 111-120.

Eisenberg, N. 2000. "Emotion, regulation, and moral development." *Annual Reviews of Psychology*, 2000, Vol. 51, pp. 665–697.

Ekman, P., Friesen, W.V., and Ellsworth, P. 1972. *Emotion in the human face: guidelines for research and integration of Findings*. New York: Pergamon.

Frijda, N. H. 1986. *The emotions*. Cambridge, England: Cambridge University Press.

Goldsmith, H. H., and Davidson, R. J. 2004. "Disambiguating the Components of Emotion Regulation." *Child Development*, March/April 2004, Vol. 75, No. 2, pp. 361-365.

Gross, J. J. 1998. "The Emerging Field of Emotion Regulation: An Integrative Review." *Review of General Psychology*, Vol. 2, No. 3, pp. 271-299.

Gross, J. J. 1999. "Emotion Regulation: Past, Present, Future." *Cognition and emotion*, 1999, Vol. 13, No. 5, pp. 551-573.

Gross, J. J. 2001. "Emotion Regulation in Adulthood: Timing is Everything." *Current directions in psychological science*, Vol. 10, No. 6, pp. 214-219.

Gross, J. J. 2002. "Emotion regulation: Affective, cognitive, and social consequences." *Psychophysiology*, 2002, Vol. 39, pp. 281–291

Hebb, D. O. 1949. *The organization of behavior: A neuropsychological theory*. New York: Wiley.

Oatley, K., and Johnson-Laird, P. N. 1987. "Towards a cognitive theory of emotions." *Cognition and Emotion*, Vol. 1, pp. 29-50.

Port, R.F., and Gelder, T. van (Eds.) 1995. *Mind as Motion: Explorations in the Dynamics of Cognition*. MIT Press, Cambridge, Mass.

Schore, A. N. 2001. "The effects of early relational trauma on right brain development, affect regulation, and infant mental health." *Infant mental health journal*, 2001, Vol. 22, No. 1, pp. 201-269

Schwarz, N., and Clore, G. L. 1983. "Mood, misattribution, and judgments of well-being: Informative and directive functions of affective states." *Journal of Personality and Social Psychology*, Vol. 45, pp. 513-523.

Thayer, J.F., and Lane, R.D. 2000. "A model of neurovisceral integration in emotion regulation and dysregulation." *Journal of Affective Disorders*, Vol. 61, pp. 201-216.

Thompson, R.A. 1994. "Emotion regulation: A theme in search of definition." In N.A. Fox (Ed.) *The development of emotion regulation: Biological and behavioral aspects. Monographs of the Society for Research in Child Development*, Vol. 59 (Serial No. 240), pp. 25-52.

ACKNOWLEDGEMENTS

I kindly want to thank Tibor Bosse and Jan Treur for their input to this paper.

AUTHOR BIOGRAPHY

MATTHIJS PONTIER was born in Amsterdam, The Netherlands, and went to the VU University of Amsterdam. He studied Artificial Intelligence as well as (Cognitive) Psychology, and obtained his Masters degree in the direction of Cognitive Science in 2007. Currently, he is employed as a PhD student at the VU University of Amsterdam, both at the department of Artificial Intelligence and the Center for Advanced Media Research Amsterdam. His e-mail address is: `mpr210@few.vu.nl`.