Available online at www.sciencedirect.com

ScienceDirect

Cognitive Systems Research 11 (2010) 211–230

Cognitive Systems RESEARCH

www.elsevier.com/locate/cogsys

A computational model based on Gross' emotion regulation theory ☆

Action editor: Ron Sun

Tibor Bosse *, Matthijs Pontier, Jan Treur

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

Received 17 July 2009; received in revised form 6 October 2009; accepted 6 October 2009
Available online 20 October 2009

Abstract

Emotion regulation describes how a subject can use certain strategies to affect emotion response levels. Usually, models for emotion regulation assume mechanisms based on feedback loops that indicate how to change certain aspects of behavior or cognitive functioning in order to get a more satisfactory emotion response level. Adaptation of such feedback loops is usually left out of consideration. This paper introduces an adaptive computational model for emotion regulation by formalizing the model informally described by Gross (1998). The model has been constructed using a high-level modeling language, and integrates both quantitative aspects (such as levels of emotional response) and qualitative aspects (such as decisions to regulate one's emotion). This model includes mechanisms for adaptivity of the degree of flexibility of the emotion regulation process. Also, the effects of events like traumas or therapies on emotion regulation can be simulated. Based on this computational model, a number of simulation experiments have been performed and evaluated.

Keywords: Emotion regulation; Adaptivity; Cognitive modelling

1. Introduction

Historically, there has been much debate about the function of emotions. For example, Hebb saw emotions as neural activation states without a function (Hebb, 1949). However, recent research provides evidence that emotions are functional (e.g., Damasio, 2000). Emotions have a facilitating function in decision making (Oatley & Johnson-Laird, 1987), prepare a person for rapid motor responses (Frijda, 1986), and provide information regarding the ongoing match between organism and environment (Schwarz & Clore, 1983). Emotions also have a social function. They provide us information about others' behavioral intentions, and script our social behavior (Gross, 1998). In the past two decades, psychological research has started to focus more on *emotion regulation* (e.g., Gross, 1998, 2001; Ochsner & Gross, 2005; Thompson, 1994). In brief, emotion regulation is the process humans undertake in order to affect their emotional response. Recent neurological findings (such as bidirectional links between limbic centers, which generate emotion, and cortical centers, which regulate emotion) have changed the consensus that emotion regulation is a simple, top-down controlled process (Gross, 1998).

This article introduces a computational model to simulate emotion regulation, based on the process model described informally by Gross (1998, 2001). Note that Gross' definition of emotion is very much related to the well known notion of coping (see, e.g., Lazarus & Folkman, 1984; Scherer, 1984), but with some subtle differences. In particular, coping mainly focuses on decreasing negative emotion experience, whereas emotion regulation addresses increasing and decreasing both positive and negative emotions (Gross, 1998).

☆ Parts of this paper are based on work presented at the 2007 international conference on cognitive modeling (ICCM'07) (Bosse, Pontier, & Treur, 2007b), the 2007 IEEE/WIC/ACM international conference on intelligent agent technology (IAT'07) (Bosse, Pontier, & Treur, 2007a), and the 2008 European conference on modeling and simulation (ECMS'08) (Pontier, 2008).

* Corresponding author.
E-mail addresses: tbosse@few.vu.nl (T. Bosse), mpontier@few.vu.nl (M. Pontier), treur@few.vu.nl (J. Treur).

1389-0417/$ - see front matter
doi:10.1016/j.cogsys.2009.10.001

Computational models for emotion regulation, like the one described in this paper, can be used for different purposes (see Wehrle (1998) for an overview). In the first place, a model for emotion regulation can be used in the field of Artificial Intelligence; see e.g., (Bates, 1994; Hudlicka, 2008). For example, in the domain of virtual reality it can be used to let virtual agents show human-like behavior regarding emotion regulation. There are also various applications one could think of for which the model could be incorporated into robots, to make them show human-like emotion regulation behavior (Reilly, 1996). Similarly, in the gaming industry, there is much interest in manners to let game characters emotionally behave like humans. Finally, computational models for emotion regulation may play a role within the field of Ambient Intelligence (Aarts, Harwig, & Schuurmans, 2001). For instance, in settings where humans have to interact intensively with automated systems, it is useful if the system maintains a model of the emotional state of the user. This can enable the system to adapt the type of interaction to the user's needs; see e.g., (Klein, Moon, & Picard, 2002).

In addition, from a Cognitive Science perspective, such a model can provide insight in the process of emotion regulation; see e.g., (Sloman, 2003). An advanced model could also be helpful to make predictions about emotions, about behavior that is a consequence of emotions and about how to influence certain behaviors with, e.g., an anger management therapy. This may be useful for the purpose of developing therapies for persons that have difficulties in regulating their emotions (Burns, Bird, Leach, & Higgins, 2003; Towl & Crighton, 1996), for example, in work with forensic inpatients.

The perspective taken in this paper is mainly the Artificial Intelligence perspective. Thus, we aim to model the process of emotion regulation in such a way that it can be incorporated into intelligent entities (e.g., intelligent virtual agents, or Ambient Intelligence systems). Therefore, a main requirement of the model is that it is relatively lightweight (i.e., easy to plug into an existing applications), while nevertheless complying with the existing literature on emotion regulation.[1]

Often, models for emotion regulation are conceptualized as dynamical systems based on feedback loops that indicate how to change certain aspects of behavior or cognitive functioning to get a more satisfactory emotion response level. Such feedback loops have certain characteristics, for example, concerning sensitivity and flexibility of the adjustments made. Too sensitive feedback loops may result in stressful and energy-consuming behavior involving frequent adjustments, whereas feedback loops that are not sensitive enough may result in long periods of less desirable emotions. To obtain a balanced form of emotion regulation, either certain more or less ideal characteristics of the feedback loops in the emotion regulation system should be set at forehand, or an adaptation mechanism should be available that allows for tuning them on the fly to the required form of sensitivity. As it does not seem very plausible to have one set of 'ideal', innate characteristics applicable in various contexts (Wehrle, 1998, p. 5), this paper takes the latter assumption as a point of departure: adaptive emotion regulation. This adaptivity includes mechanisms to assess and adapt the degrees of flexibility of the emotion regulation process over longer periods; i.e., the subject changes its willingness to change behavior in favor of emotion regulation, regarding the success of its emotion regulation in the past.

This willingness to change behavior can be changed by certain events. For instance, if someone has a very low tendency to change his/her behavior in order to regulate his emotions, a therapy could help that person to change this tendency, and help him/her 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 behavioral therapy as an approach for anger management were better off than 76% of untreated subjects, in terms of anger reduction (Beck & Fernandez, 1998). In addition, an article by Burns et al. (2003) suggests that a structured anger management training program is useful for forensic inpatients with learning disability. Finally, Deschner and McNeil (1986) 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. On the other hand, an event like a trauma could decrease the tendency to change one's behavior in order to regulate his emotions significantly. Schore (2001) describes that an early trauma can cause impaired affect regulation.

An important choice to be made in modeling is the grain size by which the model represents reality. This choice is strongly related to the goals and may have a decisive effect on the feasibility and success of a modeling enterprise. On the one hand a model that has a too fine grain size may become unmanageable both conceptually and computationally. On the other hand a model with a too coarse grain size may miss patterns in reality that may be essential to fulfill the goals of the modeling enterprise. As indicated above, the goals of the work presented here are in the area of building relatively lightweight artificial, virtual agents which have a certain level of believability. Therefore a rather coarse-grained approach has been chosen, where a number of aspects have been addressed in an abstracted manner, such as the detailed processes underlying emotion elicitation and appraisal.

In Section 2, the process model of emotion regulation by Gross is explained. The model describes a number of strategies humans use to adapt their emotion response levels, varying from situation selection to cognitive change and response

[1] However, while developing our model, we always keep the Cognitive Science perspective 'in mind'. That is, if the modeling process itself provides us new insights into emotion regulation, we will not hesitate to explore these insights in more detail.