A Dynamical System Modelling Approach to Gross' Model of Emotion Regulation (extended abstract) *

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Emotions were historically seen as neural activation states without a function. However, recent research provides evidence that emotions are functional (e.g., [4]). Emotions have a facilitating function in decision making, prepare a person for rapid motor responses, and provide information regarding the ongoing match between organism and environment. Emotions also have a social function. They provide us information about others' behavioural intentions, and script our social behaviour [5]. In the past two decades, psychological research has started to focus more on emotion regulation (e.g., [5, 6, 9, 11]). 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 [5].

This article introduces a computational model to simulate emotion regulation, based on the process model described informally by Gross [5, 6]. Such a model can be used for different purposes. In the first place, from a Cognitive Science perspective, it can provide insight in the process of emotion regulation. This may be useful for the purpose of developing therapies for persons that have difficulties in regulating their emotions [3], for example, in work with forensic inpatients. In addition, a model for emotion regulation can be used in the field of Artificial Intelligence, see e.g. [2]. For example, in the domain of virtual reality it can be used to let virtual agents show human-like behaviour regarding emotion regulation. Finally, computational models for emotion regulation may play a role within the field of Ambient Intelligence [1]. For instance, when humans have to interact intensively with automated systems, it is useful if the system maintains a model of the emotional state (and the emotion regulation process) of the user. This enables the system to adapt the interaction to the user's needs.

In this paper, a formal model for Gross' (informally described) model of emotion regulation has been introduced. The emotion regulation model has been constructed using the high-level simulation language LEADSTO as a modelling vehicle, and integrates both quantitative, dynamical system aspects (such as levels of emotional response) and qualitative aspects (such as decisions to regulate one's emotion). In the model, an important role is played by *modification factors* α_k, which could be seen as the (conscious or unconscious) willingness to change behaviour in favour of emotion regulation. Simulation experiments have been performed for different situations, by using different settings for the modification factors α_k: for ideal cases (all α_k are medium, or the α_k have different values), for cases of over-regulation (all α_k are high), and for cases of under-regulation (all α_k are low). The experiments show that different values for the modification factors α_k indeed result in different patterns.

As a preliminary validation of the model, the simulation results have been compared with the predicted behaviours for different situations as described by Gross, which are (partly) based on empirical evidence [5, 6]. The patterns produced by the model were found consistent with Gross' descriptions of examples of human regulation processes. Validation involving extensive comparison with detailed empirical data is left for future work.

Although the process of emotion regulation is widely investigated in the literature (e.g. [5, 6, 9, 11]), not so many contributions address the possibility of developing a computational model of this process. The computational models that have been developed so far either address some very specific aspects of the process at a more detailed (neurological) level, see e.g. [10], or they aim at incorporating emotions

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into software agents, in which case they focus more on emotion elicitation (appraisal) than on emotion regulation, see e.g. [2]. The current paper can be seen as an attempt to build a bridge between both directions. It formalises an existing theory about emotion regulation using a high-level modelling language, but still in enough detail to be able to generate useful simulation traces. As such, it has similarities with the work by Marsella and Gratch [8], who propose an approach to incorporate both appraisal and coping behaviour into virtual humans. Their approach makes use of plan-based causal representations, augmented with decision-theoretic planning techniques, whereas our approach uses dynamical systems representations. Other differences are that they propose a "content model", in which appraisal and regulation operate on rich representations of the emotion-evoking situation, and that their work has been evaluated against clinical data.

The presented model is still in an early stage of development. For example, the modification factors α_k are currently fixed. In order to make the model adaptive, these factors can be made adjustable. A way to accomplish this is to adapt the values of the α_k to one's satisfaction about the past emotion regulation process. This way, the model could simulate cases in which humans learn to select the ideal situations, as in certain types of therapy. Another possible extension to the model would be to make the desired emotion response level ERL_norm dynamic, so that it can depend on specific circumstances. A final extension would be to represent the different elements k using more complex knowledge structures, and to enable the model to dynamically derive the different emotional values from these structures, as is done, for example, in [7]. Future work will explore such possibilities.

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