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## A blueprint for an affectively competent agent

### Cross-fertilization between Emotion Psychology, Affective Neuroscience, Philosophy, and Affective Computing

Editors

Tanja Bänziger, University of Geneva

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#### Overview

This volume is proposed as a source book and manual for all those interested in computational models of emotion based on the state of the art in current scientific investigation of affect in Emotion Psychology and Affective Neuroscience. Its aim is to present systematic theoretical conceptualizations of the processes underlying emotional reactions and their implications for various fields in applied Affective Computing.

The focus of the core contributions is an accessible description of the structures, functions, and mechanisms underlying emotional reactions; including processes involved in the elicitation of emotional responses, as well as expressive and physiological responses generated during emotional responses, and interpersonal perception of emotional responses.

The proposed book will take the form of a dialogue between conceptualizations and propositions grounded in Emotion Psychology, in Affective Neuroscience, in Philosophy and in several areas of Affective Computing. Its overarching goal is to outline how the perspectives of those different disciplines can inform each other and how this cross-fertilization can give rise to new perspectives and questions in the considered research fields.

#### Section and chapter organisation

The proposed book is organised in five sections. The **first, introductory, section** will set the ground for the volume and emphasize the need to relate theoretical propositions as well as empirical data gathered in psychological and in neuropsychological studies to operating models used in affective computing. It will illustrate, using selected examples, how psychological models and theories dealing with emotional responses might, in principle, benefit from being "translated" (operationalized) into computational terms. Reciprocally, it will also outline the purported benefits for computational models to integrate theoretical propositions and empirical results from other disciplines.

The **second section** will present the state of the art in current scientific investigation of affect in Emotion Psychology and/or Affective Neuroscience. The individual contributions (chapters) in this section will be articulated around different components of emotional responses (e.g. processes involved in the elicitation of emotional reactions; physiological reactions involved in emotional responses; expressive behaviour and interpersonal communication in emotional episodes). Each chapter in this section will include several propositions regarding the theories (models) and/or the empirical knowledge that might be

usefully applied to affective computing. Such propositions might include suggestions to test specific predictions made in the respective fields using computational models (or expressive embodied agents), as well as suggestions aiming at improving operating models in affective computing (i.e. enhancing the "affective competence" of the computers on the basis of models and/or data available in the respective fields).

The **third section** will outline a philosophical perspective on emotional feeling and emphasize the importance of this perspective for the design of an affectively competent agent.

The **fourth section** will introduce the perspectives of several applied domains in engineering and computer sciences on emotional reactions and their conceptualization in the respective fields. Individual contributions (chapters) in this section will be articulated around different applications (e.g. expression of emotion in embodied conversational agents, neural network models of emotional processes). Each chapter in this section should address one or more proposition(s) raised in section 2 and/or in section 3 and discuss its feasibility with respect to the state of the art in the respective applied field. Each chapter should also, on a more general level, outline an own perspective on the possibilities and the limitations of the current technologies and methods available in engineering and computer sciences to address and/or incorporate the models and paradigms developed by psychologists and neuroscientists, or the propositions formulated by philosophers, for the study of emotional reactions.

The **fifth, concluding, section** will attempt to integrate some of the views presented in the chapters of the earlier sections and will raise tentative propositions regarding the possibilities to enhance the cross-fertilization across disciplines with respect to the study of emotions in humans and in machines. Based on the contributions of the earlier sections, the last section should also include tentative conclusions regarding the minimal characteristics (specifications) of an "affectively competent agent" and tentative predictions regarding the prospective of such an agent in the near and distant future.

## Provisional table of contents (chapters and contributors)

### Section 1 – Introduction: the study of emotions in humans and in machines, attempt to "bridge the gap"

#### Introduction (editorial)

*Authors: T. Bänziger, K. R. Scherer*

Summary: This introductory note will provide an overview of the volume. Its aim is to outline the contents and the issues addressed by the book. Among others: how did the idea of a "blueprint for an affectively competent agent" emerge? Why do we try to "bridge the gap" between disciplines and relate emotions in humans to emotions in machines (computers)?

#### Computational Models of Emotion

*Authors: S. Marsella, J. Gratch, P. Petta*

Summary: Recent years have seen the emergence of a true interdisciplinary partnership between emotion research and computational science. This has led to a significant growth in research on computational models of human emotional processes, fueled both by their basic research potential as well as promise for application. Such models are transforming theory construction by providing a framework for studying emotion processes that goes beyond what is feasible in more traditional laboratory settings – computer simulations of the model provide a means to question traditional conceptualizations, expose hidden assumptions, and to explore systematically the temporal dynamics of emotion processes and form predictions about the time course of those processes. Modern research in the psychology, cognitive science and neuroscience of emotion is also transforming the science of computation – findings on the functional, often adaptive role that emotions play in human behavior have motivated artificial intelligence and robotics research to explore whether modeling emotion processes can contribute to making progress in elusive areas such as perception and lead to more intelligent, flexible and capable systems. Finally, as research has revealed the deep role that emotion and emotion expression play in human social interaction, researchers in human computer interaction have proposed that more effective human computer interfaces can be realized if the interface models the user's emotion as well as expresses emotions – researchers in virtual characters for gaming and teaching environments have sought to endow virtual characters with emotion-related capabilities so that they may interact more naturally with human users. In this article, we discuss in detail these roles for computational models of emotion: a methodological tool for emotion theories, a new approach to artificially intelligent systems and a means to enhance human-computer-interaction. We cover both current uses of computational models as well as possible future directions for this research and its potential impact on emotion research.

## **Section 2 – Psychological, and neuropsychological perspectives on emotions: propositions for affective computing**

### **Emotion and emotional competence: Conceptual and theoretical issues for modeling**

*Authors: K. R. Scherer*

Summary: This chapter provides a description of the elements theoretically needed to construct a virtual agent with the ability to display human like emotions and to respond appropriately to human emotion. It includes distinctive definitions of affective concepts, and a definition of emotional competence in this context. The chapter presents a comparative overview of psychological models/theories and their relative advantages or disadvantages with respect to the computational modeling of the proposed mechanisms. As different theories cover different aspects of emotion, it is discussed how their contributions can be integrated. The chapter concludes with a survey of desirable features for emotion theories that make them ideal blueprints for agent models.

*A first draft of this chapter is available.*

### **The Component Process Model: A blueprint for a comprehensive computational model of emotion**

*Authors: K. R. Scherer*

Summary: This chapter provides a detailed description of the component process model of emotion as elaborated by Scherer and his collaborators. The fundamental mechanisms of emotion-antecedent appraisal on different levels of processing is described in detail. Then the component patterning predictions are derived, showing how response patterns in different modalities are to be expected as results of the sequential cumulative appraisal checks. The model and its predictions are buttressed by extensive empirical evidence now available from research in psychology and the neurosciences. In conclusion, a first attempt is made to examine the ways in which the model could be implemented in a computational form.

*A first draft of this chapter is available.*

### **The Appraising Brain in Virtual Humans I: Theoretical Considerations from the Cognitive Neuroscience of Emotion**

*Authors: D. Sander, D. Grandjean*

Summary: This contribution will discuss how advances in cognitive neuroscience allow a better understanding of both the domain and the mode of processing of emotional mechanisms. A critical review of current cognitive neuroscience models of emotion will be proposed, and it will be argued that a computational analysis of emotional processes, together with the identification of the neural mechanisms subserving these processes, can serve to constrain and inform psychological models of emotion. Finally, the contribution will discuss how a better understanding of the appraising brain

(i.e., neural networks subserving appraisal mechanisms) can guide, and benefit from, computational studies in virtual humans.

### **The Appraising Brain in Virtual Humans II: Microgenetic dynamics of emotional processing**

*Authors: D. Grandjean, D. Sander*

Summary: The temporal unfolding of cognitive processes involved in an emotional episode is a crucial problem in the modelling of emotional processes in virtual agents. Theoretical considerations will be discussed in the light of appraisal models considering emotions as dynamic processes rather than static states. In this theoretical perspective the temporal dimension cannot be excluded from the phenomena of cognitive processes involved in the genesis of emotions. Beyond these temporal aspects, the different levels of processes will be discussed in the light of recent empirical findings in the neuroscience field. Dynamic and functional coupling of brain regions distant from one another involved in the genesis of emotion will be also discussed. Theoretical considerations as well as recent empirical results will be presented in terms of their contribution to building a model of emotion in virtual environments.

### **The face and voice of emotions: the expression of emotions**

*Authors: T. Bänziger, S. Kaiser*

Summary: The aim of this chapter is to outline how psychological models and empirical research on facial and vocal emotional expressions can both inform applications in affective computing and benefit from applications in affective computing. The chapter will include a brief review of psychological research in the domain of both production (encoding) and perception (decoding) of facial and vocal emotional expressions. This will comprise descriptions of postulated mechanisms, such as descriptions of the various determinants theoretically involved in the generation of emotional expressions (e.g. physiological determinants and socio-cultural determinants), and descriptions of potential mechanisms involved in the perception (perceptual processing and recognition) of facial and vocal emotional expressions. The chapter will outline the predictions formulated by several psychological models regarding both facial behavior and vocal behavior associated with emotional reactions. Specifically, it will introduce and compare predictions issuing from an evolutionary-functionalist perspective and predictions issuing from a cognitive approach to emotional reactions. Issues related to emotional regulation (automatic and strategic control of expressions) and nonverbal sensitivity to emotional expressions will be addressed. The relevance for affective computing (e.g. for the generation of emotional expressions in ECAs, or for the automatic recognition of emotional expressions) of the models and empirical results outlined in this chapter will be systematically examined.

## **Psychophysiological response patterning in emotion: Implications for affective computing**

*Authors: S. Kreibig, T. Brosch*

**Summary:** The aim of this chapter is to give an overview of emotion-related changes in autonomic systems. The mechanisms and functions of the cardiovascular, electrodermal, respiratory and facial muscular systems as well as their main response indices are the focus of the first part of this chapter. We next introduce central predictions of different emotion theories for physiological response patterning, present major empirical findings, and discuss current research issues. We conclude by showing potential and actual applications of the analysis of physiological responding in affective computing (sensing, recognizing, and expressing emotions).

## **Emotions in Interpersonal Interactions**

*Authors: B. Parkinson*

**Summary:** This chapter discusses the various ways in which emotions affect and are affected by interpersonal life in order to identify the challenges faced by simulations and models of these socially embedded processes. The first section reviews interpersonal causes of emotion, focusing on how other people impact on the process of appraisal, and addressing the question of whether appraisal-independent effects on emotion are possible. In particular, this section evaluates evidence relating to social appraisal, emotion contagion, and audience effects on facial expression. Although each of these phenomena may be modeled at the level of an individual agent, some of their emergent, dynamic features may be best captured using simulated inter-agent transactions. The next section discusses literature on the interpersonal effects of emotion, including the use of emotions in persuasion and negotiation. Based on this literature, the chapter develops a social functionalist account of emotion presentation and distinguishes between the implicit interpersonal orientation of some emotions, and the more widely applicable interpersonal regulatory aspects of strategic emotion presentations. Cybernetic models may need to be extended to accommodate the observation that the former “social” emotions are intrinsically attuned to the unfolding structure of a responsive interpersonal, organizational, and practical environment.

## **Databases for Affectively Competent Agents**

*Authors: R. Cowie, E. Douglas-Cowie, J.-C. Martin, L. Devillers*

**Summary:** Databases are essential for some aspects of the design of affectively competent agents, and highly desirable for others. In contemporary technology, the only practical way to engineer many subsystems is by constructing suitable databases and applying learning algorithms to them, not by a human designing in the conventional sense. For instance, learning is likely to extract the weightings that allow a system to recognise either phonemes spoken in an emotional way, or the emotion underlying the speech; to find the parameters that yield emotionally convincing gestures;

and so on. These learning-based parts of the design process absolutely require suitable databases to learn from. Even where psychologists will use traditional scientific procedures to articulate rules that govern some aspects of an agent's behaviour, there are obvious advantages if the research can exploit permanent databases of carefully assembled and validated recordings, rather than trying to generate the required kind of material for every new study (and perhaps not succeeding completely). Work on appropriate databases has gathered pace in the last decade. It has to address problems at multiple levels: psychological (what should ideally be recorded and how it should ideally be described); practical (suitable recording techniques, reliability of labelling, ease of use); and legal/ethical (consent, ownership and data protection). Balances between generality and task-specificity are a recurring problem. Emerging ideas in the field are described in the context of particular databases that reflect the state of the art.

### **Section 3 – A philosophical perspective on emotional feelings: implications for affective computing and suggestions for the "design" of an affectively competent agent**

#### **Getting Feelings into Emotion in the Right Way**

*Authors: P. Goldie*

Summary: Consideration of the phenomenology of emotional experience—what it is like—strongly suggests that feelings are centrally important. However, it is no easy matter to give an account of the feelings involved in emotional experience that is faithful to its phenomenology, and this is what I want to try to do: we will not have got feelings into emotion in the right way unless we achieve this. What some accounts tend to do, very roughly, is to draw a fundamental divide, decomposing the mental, including emotional experience, into thought and perception on the one hand and feelings on the other, with thought and perception to be understood in terms of ‘access consciousness’, and explained in information-processing terms; and with feelings, to be understood in terms of ‘phenomenal consciousness’—the so-called ‘hard’ problem of consciousness. What I will argue for is the view that there are emotional feelings of a kind that, like thought and perception, can be directed immediately towards objects in the world beyond the bounds of the body. These feelings are bound up with cognition but are not reducible to belief or to perception, or to any other kind of cognition; they are, rather, *sui generis*. They are what I call *feelings towards*. If feelings towards do have this *sui generis* character, then the question arises as to how one might attempt to integrate them into an 'affectively competent agent'. Will such an agent have to be one which is capable of consciousness in the full-blooded sense of being an agent with a point of view on the world? In other words, in the sense elucidated by Thomas Nagel, would there have to be 'something that it is like' to be such an agent? Without that, how could such an agent be truly said to be emotional?

## **No Need for Inferences: Affective Perception**

*Authors: S. A. Döring*

Summary: This chapter discusses how cognitivism in the philosophy of emotion may contribute to enhancing the affective competence of computational agents. By now, it is common ground among philosophers that emotions are cognitive in the sense that they are about something and represent that thing as being a certain way. What is less clear is how an emotion's representational content can be integrated with its phenomenology, its feeling or 'what-it-is-like'. Feeling is essential to emotion, and that is why so much research on affectively competent agents is research on the expression of feeling and on the physiological reactions that are supposed to constitute feeling. The focus of this chapter is somewhat different. My question is how the integration of representation and feeling is reflected in the emotions' cognitive role. Before a computational agent can prove its affective competence in expressing an emotion credibly, it must first be able to determine which emotion is appropriate in a given situation. That is, an affectively competent agent must be able to appraise the situation in the right way. I argue that emotional appraisal takes the non-inferential form of perception. It is gestalt-like. This philosophical theory of emotion is related to psychological appraisal theories.

## **Section 4 – Emotions in applied affective computing: how do (or could) they integrate propositions from psychological and neuropsychological models**

### **Emotions in Artificial Neural Networks**

*Authors: E. Roesch, N. Korsten, N. Fragopanagos, J. Taylor, K. Scherer*

Summary: Artificial Neural Network (ANN) modeling is concerned with the description of the brain and its function through a variety of theoretical constructs and computer analogies (Arbib, 2003). In this chapter, we aim at bringing together this applied approach with the theories of emotion and attention described by Psychology and Cognitive Neuroscience. To that end, we will use the paradigm of the "Attentional Blink" (Raymond, Shapiro, & Arnell, 1992) as our main focus, describing some of the latest experimental results, and their accounts brought by modeling. This chapter will be structured as follows. We will first describe some of the most influential theories of emotions, and the counterpart data provided by Cognitive Neuroscience research, applying a "computational lens" to this knowledge. We will then do the same exercise to the description of the cognitive function of attention. Finally, we will propose a framework to bridge the gaps between these two research areas, in the form of the research paradigm using the modulation of the attentional blink phenomena by emotional stimuli. We will conclude by describing a biologically plausible ANN that, we argue, will allow to

disentangle some of the questions arising from emotion and attention research.

### **Emotional behaviors in ECAs**

*Authors: C. Pelachaud, M. Mancini*

**Summary:** In this chapter we address the problem of generation of emotional expressive behaviors in Embodied Conversational Agents. First we will explain how we derived our expressivity model based on theoretical propositions and empirical data issued from the study of emotional expressions in humans. Then we will describe the set of parameters we are using to represent behavior expressivity and how these parameters have been implemented. We have used this model in a series of studies. In particular, the set of parameters was used not only to synthesize behaviors but also to annotate manually as well as to analyze automatically behaviors expressivity from video corpora. In this chapter we will report of our use of different types of empirical data to learn and refine our computational model of expressive behaviors.

### **Synthesis of emotional speech**

*Authors: M. Schröder, F. Burkhardt, S. Krstulovic*

**Summary:** Speech generated by an affectively competent agent would ideally model emotions in a way that is motivated by models from emotion theory. However, the current state of the art in expressive speech synthesis is mostly determined by pragmatic considerations and technological limitations, and shows only limited grounding in emotion theory. This chapter discusses the current situation, identifying two types of challenges that should be addressed in order to approach the ideal speech capabilities for an affectively competent agent. A technological challenge arises from the fact that existing synthesis technologies are either natural-sounding or allow for a flexible control of acoustic parameters, but not both. After giving a brief historical overview of the current state of affairs, we look in more detail at two approaches, rule-based synthesis based on production models, and data-driven statistical models. A methodological challenge is to ground generative models of emotional prosody in theoretically motivated models of emotion, overcoming current practice where emotional prosody rules are often formulated for a limited set of unrelated emotion categories. We report on first steps in this direction using a coarse emotion description in terms of emotion dimensions, and suggest a more elaborate approach based on an appraisal model.

### **Automatic detection of emotion from vocal expression**

*L. Devillers, L. Vidrascu*

Summary: Automatic emotion detection by an affectively competent agent would ideally be based on a model of the dynamic emotion process. This idea is linked to Scherer's theory in that it tackles the dynamic and constantly changing nature of the expression of emotions. It is in contrast to many of the current engineering models of emotion that assume unambiguous responses to fixed conditions considering a static model of emotion. In this chapter, we first review the most important aspects of past research on the speech/voice related aspects, i.e. commenting upon issues concerning noise, standard speech sample problems, spontaneous real-life data, acoustic convergence between speakers, etc. Second, we describe the components of automatic recognition of emotion conveyed by speech based on statistical approaches. The set of acoustic and linguistic features which are currently used in the scientific community is also reported. After giving the “best practices”, we present the current state of the art in the domain. Finally, we will present the challenge of trying to overcome the limitation of the current technology by suggesting new approaches based on appraisal model such as getting the issues of dynamic unfolding of vocal cues.

### **Human full-body movement, gesture and facial expressions analysis for automatic emotion recognition**

*Authors: A. Camurri, G. Castellano, K. Karpouzis, S. Kollias, G. Volpe*

Summary: One of the main requirements of emotion-oriented systems concerns the recognition of emotions in users. Emotion recognition requires to consider emotional processes as multimodal phenomena. In this chapter we focus on the analysis of non-verbal multimodal data from users for the understanding of emotional information. In particular, we study human full-body movement, gesture and facial expressions as channels (or components) that contribute to explain emotions. We present the state of the art of computational models and techniques for the automated analysis of the emotional state in subjects, focusing on the links with theories and models derived from psychology. Further, we explain limitations of current approaches and present results and future directions of investigation.

## **Section 5 – Conclusions: the study of emotions in humans and computers, similarities and differences, present and future**

The last section of this volume will include comments and discussions on a number of major open or controversial issues. The exact number and nature of those issues will be defined by the editors (with input of the co-authors) on the basis of the contributions included in the preceding sections. Such topics might include:

**Ethical issues raised in the volume: do we need and do we want an "affectively competent agent"?** Based on the previous chapters, what do and what should we expect from an "affectively competent agent"; should an "affectively competent agent" compare with an emotional human being; what are the major foreseeable benefits and the major foreseeable risks, with respect to current technologies (outlined in the earlier chapters) and with respect to "science fiction" (speculations regarding future technologies).

**Minimal requirements for an affectively competent agent.** What should the minimal specifications (characteristics) of an "affectively competent agent" include; does/will an "affectively competent agent" (ever) compare with an emotional human being.

**Feasibility and implications of a multidisciplinary approach to the study of affective reactions.** Is there a gap between psychological models, philosophical perspectives, and computational models of emotions? What are the areas of existent and/or potential cross-fertilizations as defined in the earlier sections. Compatibilities and incompatibilities of different approaches to the study and modeling of emotional responses.

The authors of earlier sections (from various disciplines) will be invited to comment (or to dialogue) on the identified issues.

### **Timeline for completion**

A book proposal dated February 2007 has been submitted to Oxford University Press. We are currently awaiting the publisher's evaluation of the project.