# Virtual Humans Growing up: From Primary Toward Secondary Emotions

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**In order to understand and model the role of emotion in cognitive processes we attempt to integrate theoretical approaches originating from different disciplines in an implemented cognitive architecture for embodied agents. Our virtual humanoid agent Max employs this architecture to generate believable human-like behaviors in a variety of situational contexts. In this article, we describe how we go about endowing Max's architecture with increasingly elaborated kinds of emotions – from primary emotions like happiness and fear, toward secondary emotions like hope and relief.**

## 1 Introduction

In recent years the integration of "emotion-driven" behaviors has become prominent in the field of virtual humans [7] for at least two reasons: First, the integration of emotions—or at least emotional expressions—is supposed to support the believability of the artificial interlocutor in Human-Computer Interaction. Second, from a more theoretical point of view it is argued that without the integration of non-rational concepts, such as emotion, the ultimate step toward human intelligence might never be accomplished by Artificial Intelligence.

The virtual human Max, developed at Bielefeld University's AI Group, is a testbed for studying human-like behavior in natural face-to-face interactions [9]. We describe here how we incrementally endow Max's cognitive architecture with simulated emotions. In this we follow Damasio's [4] distinction of "primary" and "secondary" emotions. Primary emotions are onto-genetically older types of emotions and they lead to basic behavioral response tendencies like "flight-or-fight" behaviors. They are elicited in immediate response to stimuli that might also originate from internal, bodily processes. In contrast, secondary emotions like "relief" or "hope" are assumed to arise from higher cognitive processes, based on an ability to evaluate preferences over outcomes and expectations.

In Section 2 we present theoretical approaches in psychology to shed light on the somewhat fuzzy concept of emotion. After introducing an integrated architecture in Section 3, we will describe in Section 4 how we started out with simulating primary emotions. Comparable to human children, Max directly reveals his primary emotions by modulated involuntary behaviors and changing facial expressions. In human adults, however, a smile may as well be connected to a secondary emotion as, e.g., relief. In Section 5 we present how we have started to model the higher-order cognitive processes that underlie the simulation of secondary emotions. We will thereby show how our growing up agent is becoming able to experience increasingly elaborated kinds of emotions and how these extensions advance his abilities to interact in a gaming scenario.

## 2 Background

The concept of emotion has long been subject to controversy in psychology. Two major strands of theories can be distinguished. *Cognitive* emotion theories are focusing on the cognitive appraisal processes [20] and structures [12] necessary to elicit the full range of emotions in adult humans. On the other hand (and not to be treated completely in separation as we will see), *dimensional* emotion theories [5] are based on the idea to classify emotions along a varying number of dimensions of connotative meaning [14]. In the following, we will present these strands of theories in more detail and report on computational systems that integrate emotions into their architectures.

### 2.1 Emotion theories

The emotion model proposed by Ortony, Clore and Collins [12] (in short, OCC) has often been the basis for modeling emotions in cognitive architectures of embodied characters. In this conceptual model, a total of 22 emotion categories are differentiated that can be deduced logically from events, agents and objects. Although explicitly designed to be applied computationally, it was frequently criticized for major methodological drawbacks. Recently, Ortony et al. [13] have argued for distinguishing three levels of information processing that give rise to different classes of affective states. "Proto-affect" is considered a product of lower-level, hard-wired, reactive processes. "Primitive and unconscious emotions" arise from routine level processing characterized by awareness without self-awareness. At last, the reflective level gives rise to "full-fledged, cognitively elaborated emotions" originating from higher-order cognitive functions.

In contrast to the conceptual OCC approach, Scherer's "component process model" identifies different functional sources of emotion elicitation and proposes five distinct components, in which the regulatory functions reside [20]. Notably, these components can also be associated with corresponding parts of the human nervous system. As these components are assumed to process "stimulus evaluation checks" (SEC, in short) in parallel, timing and synchronization are central to this theory.

With regard to the different degrees of awareness and conscious processing, Damasio's [4] primary emotions are understood as basic, more automatic behavioral response