Affective Gaming in Education, Training and Therapy: Motivation, Requirements, Techniques

Eva Hudlicka
Psychometrix Associates, Inc.
Amherst, MA
hudlicka@ieee.org
psychometrixassociates.com

Abstract

Games are being increasingly used for educational and training purposes, because of their unique ability to engage students, and to provide customized learning and training protocols. In addition, games are being developed for health-related education and training, for cognitive and motor rehabilitation, and, more recently, for psychotherapy. Emotion plays a central role in learning, in the training of new cognitive and affective skills, and in the acquisition of new behaviors and motor skills, as well as in the eliminations of undesirable behaviors (e.g., addictions). This chapter discusses how the emerging discipline of affective gaming contributes to the design of more engaging and effective educational and training games, by explicitly integrating emotion into the gameplay. It focuses on the contributions from affective computing, and emphasizes the important role of emotion modeling. Emotion modeling is relevant both for modeling emotions in game characters, to enhance their believability and effectiveness, and for the development of affective user models, to enable real-time gameplay adaptation to the player’s changing affective state. The chapter introduces the notion of affect-centered games: games whose central objective is to train affective or social skills. It also discusses several concepts facilitating the design and evaluation of affect-centered games: affective player profile, affective gameplay profile and ideal affective player envelope. The chapter discusses approaches to modeling emotion in game characters, and concludes with a discussion of a tool that would facilitate the development of affect-centered games: an affective game engine.
Introduction

Games are being increasingly used for educational and training purposes, for a variety of specific topics and domains (language, biology, mathematics, motor skills, cognitive skills, healthcare and medical training, military training). Games have a unique ability to engage students, and to provide customized learning and training protocols. This makes serious educational and training games a powerful tool for teaching and training. In addition, games are being developed for health-related education, training and cognitive and motor rehabilitation. Examples include games for education about healthy diet and exercise (e.g., Escape from Diab (archimage.com), Squire’s Quest (http://www.squiresquest.com); and games for motor rehabilitation following stroke or brain trauma (e.g., (Burke, McNeill et al., 2009).

More recently, use of games has been suggested for psychotherapy (Brezinka and Hovestadt, 2007), and psychoeducation, for a variety of disorders, conditions and life-skills; e.g., stress reduction, smoking cessation, obesity prevention. Within the past few years, games have begun to emerge that directly address psychotherapy; e.g., a game designed to support cognitive-behavioral treatment in children for example Treasure Hunt (Brezinka, 2008)); a game for children experiencing divorce, based on family therapy (www.ziplandinteractive.com); and a game designed to motivate adolescents for solution-focused therapy (“Personal Motivator”, (Coyle, Matthews et al., 2005).

Emotion plays a central role in learning, in the training of new cognitive and affective skills, and in the acquisition of new motor skills. Emotion is also critical for the acquisition of new behavioral skills, as well as for the elimination of undesirable behaviors (e.g., addictions).

The emerging area of affective gaming (Sykes, 2004; Gilleade, Dix et al., 2005) is therefore directly relevant to the development of educational, training, and therapeutic games. Affective gaming focuses on the integration of emotion into game design and development, and includes the following areas: recognition of player emotions, adaptations of the gameplay to the players’ affective states, and modeling and expression of emotions by non-playing characters.

This chapter discusses how the emerging discipline of affective gaming contributes to the design of more engaging and effective educational, training and therapeutic games, by explicitly integrating emotion into the gameplay. The chapter focuses on the contributions from affective computing, and emphasizes the important role of emotion modeling. Emotion modeling is
relevant both for modeling emotions in game characters, to enhance their believability and effectiveness, and for the development of affective user models, to enable real-time gameplay adaptation to the player’s changing affective state.

The chapter focuses in particular on affect-sensitive games, which are capable of recognizing and adapting to the player’s emotional state. It introduces the notion of affect-centered games, which are games where emotions play a central role, and whose explicit purpose is to train affective and social skills, or to aid in psychotherapy. The chapter also discusses several concepts that facilitate the design and development of educational, training, and therapeutic games, including the notions of affective player profile, affective gameplay profile, and the optimal affective envelope of the player. The chapter concludes with a discussion of an affective game engine (Hudlicka, 2009): a tool that would facilitate the development of affect-centered games, by providing the necessary embedded representational and knowledge primitives, and algorithms, to support more systematic affect-focused game design.

This chapter is organized as follows. First, the importance and role of emotion in learning and training is briefly discussed the next section, the affect-related constructs outlined above are defined, and their relevance for the design of educational and training games in general, and affect-centered games in particular, are discussed section “Affect-Related Constructs Useful for Educational Game Design”. Next, the notion of affect-centered games is elaborated, and contrasted with more traditional educational and training games, in section “Affect-Sensitive and Affect-Centered Games”, and some central issues for their design are highlighted in section “Affect-Focused Game Design”. Next, background information on emotion research in psychology is provided in section “Emotion Research Background”, followed by an introduction to the emerging area of affective gaming (section “Affective Gaming”), and a brief overview of affective computing, and its relevance for affective gaming (section “Affective Computing”). Some of the requirements for the development of affect-sensitive and affect-centered educational games are then discussed (section “Requirements for Developing Affect-Sensitive and Affect-Centered Games”), followed by a discussion of approaches available to model emotion generation and emotion effects in non-playing characters (section “Methods for Modeling Emotions in Game Characters and Player Models”). Finally, the notion of affective game engines is introduced, and the need for such a tool is discussed, along
with some of its functionalities (section “Affective Game Engines”). Key design issues and choices are then highlighted (section “Summary and Recommendations”) and recommendations for researchers, practitioners and policy-makers are summarized. The chapter concludes with a summary and discussion of the key challenges in the development of affective games for education, training and therapy.

A brief note on terminology. The term affective states covers emotions, moods and undifferentiated positive or negative affect. The term emotion refers to short-lasting, recognizable states with specific, known triggers (e.g., joy, anger, frustration or sadness). The term mixed cognitive-affective states covers states such as confusion, engagement, or flow, which cannot be considered purely affective but have a strong affective component.

**Emotions and Personality in Learning and Training**

Emotions play a critical role in motivation and exert strong effects on all aspects of cognition (LeDoux, 2000; Mineka, Rafael et al., 2003; Slovic, Finucane et al., 2004). Emotions and moods influence both the fundamental cognitive processes such as attention and memory (both encoding and recall), and higher-level cognitive processes such as situation assessment, problem-solving, planning, goal management and decision-making.

It is well established that some affective states, and mixed states, are conducive for learning; e.g., curiosity, excitement, engagement, and flow (Kort, Reilly et al., 2001). Research in affective biases on cognition provides evidence about the specific reasons why positive states improve learning. For example, happiness promotes more creativity in problem-solving, and more effective elaboration and encoding of memory (Mellers, Schwartz et al., 1998). In contrast, many affective states, such as boredom, frustration, fear and anxiety, are detrimental to learning. Interestingly, positive states aren’t necessarily always good and negative states aren’t necessarily always bad, providing their intensity is not extreme. For example, affective bias research suggests that negative emotions such as sadness are associated with increased analytical thinking, whereas positive emotions are associated with the use of heuristics and shortcuts (Mellers, Schwartz et al., 1998; Mineka, Rafael et al., 2003). While it would be bizarre to conclude that we should therefore induce sadness in students to promote analytical thinking, this finding does suggest that strong positive emotions may not always be the most desirable states.
for all aspects of learning or training.

To be effective, educational and training games need to track the student’s mental state, particularly affective and mixed affective-cognitive states, identify states which are detrimental to learning, and modify the gameplay to reduce their intensity and frequency.

There is great individual variability in the affective states that specific students typically experience, in the triggers that induce these states, and in the manner in which these states dissipate and transform into other states. We discuss this below in the context of individual affective profiles. Learning and training games must take such individual profiles into considerations to ensure that the gameplay appropriately adapts to the students’ individual and idiosyncratic affective needs. There are also differences in the general learning styles and motivational patterns among students, associated with their personality (which influences, indeed defines, the student’s affective profile). For example, some individuals are motivated by reward, others by fear of failure (Matthews and Deary 1998). To be effective, educational games must take such individual differences into account and adapt the gameplay accordingly.

### Affect-Related Constructs Useful for Educational Game Design

Several constructs are useful for the design and evaluation of affect-sensitive and affect-centered games for education, training and therapy:

- **affective player profile**;
- **affective gameplay profile** of the player during a particular gameplay; and
- **ideal affective envelope** for the student during the gameplay.

These constructs provide a basis for precise and quantitative descriptions of the players’ affective states, as it relates to learning in general, and the gameplay in particular. Below we discuss these constructs, and their role in supporting the design of engaging games.

*Affective player profile* refers to the a description of the typical affective states the player experiences, typical triggers of these states, and typical behaviors associated with these states, all within the context of a particular game. The profile can be quite elaborate, and include also the associated cognitive biases and internal emotion effects, as they relate to the player’s motivation and learning during gameplay. Different players will have different affective profiles, and the information in an affective profile is the basis for developing specific gameplays to meet the learning goals and needs of the student.
The related construct of an **affective gameplay profile** refers to the specific set of affective states experienced within a particular gameplay sequence, along with the specific triggers associated with transitions among states, and gameplay behaviors associated with each state. The affective gameplay profile is thus an instantiation of the more generic affective player profile discussed above, within a specific gameplay context. The same player can experience different affective gameplay profiles, depending on their mood, or their progression through the training protocol.

The affective player profile serves as a basis for designing optimal learning and training scenarios. The affective gameplay profiles then serve to track the actual affective states the player experiences during gameplay, and provide a basis for modifying the gameplay to meet the player’s goals and needs. For example, if the affective gameplay profile consistently indicates that the player experiences significant amounts of frustration, the information in the profile (e.g., frustration triggers) can be used to modify the gameplay, to reduce these undesirable states.

An **ideal affective envelope** for a particular player-game interaction specifies the desired affective states, along with their intensities, for a particular set of learning or training goals, for a specific player-game context. The ideal affective envelope can be defined both in terms of the core dimensions of affect (typically arousal and valence), but also in terms of specific affective states, including both short-lasting emotions (e.g., joy, anger, sadness), and longer-lasting moods. Mixed states such as confusion, engagement and flow can also be included in the optimal affective envelopes. The ideal affective envelope then serves as a design goal for the game developer, and the game can be evaluated with respect to this goal, to assess how closely it meets the learning goals and needs of the student.

**Affect-Sensitive and Affect-Centered Games**

All games induce some emotions in players. When the gameplay is successful, these emotions are primarily positive, and encourage the player to continue engaging with the game. In the case of educational, training or therapeutic games, an additional benefit is that the player is acquiring new skills or knowledge, or experiencing a reduction in some undesirable symptoms.

When the games are not designed properly, or if there is a poor match between the game and the player interests and skills, games may induce negative emotions in the player (e.g.,
frustration, boredom, confusion), and the player abandons the game. In the case of educational games, little or no learning then takes place.

The degree of explicit focus on players’ emotions in gaming and game design varies. Players’ emotions may be a “side effect” of the game, with not much conscious thought given to emotion during design: as long as the game ends up being more ‘fun’ than ‘frustrating’, the players remain engaged and their emotions can be ignored by the designers.

The players’ emotions can also function as a means-to-an-end, to control the players’ engagement within the game. This requires more systematic attention to the players’ affective reactions. This can be achieved through an “open-loop” approach. This approach does not require the game system sense the player’s emotions, since the game can adapt through carefully structured levels, plot lines and sequences of increasingly difficult actions, required to achieve the ultimate game goal, or through game character behavior such as taunting or encouragement.

In contrast with this approach, the player’s emotions can be incorporated into a game in a “closed-loop” manner, where they are sensed and recognized by the game system. Some aspect of the game is then modified, as a function of the player’s state: the game is made less challenging if the player becomes frustrated, and more challenging if s/he becomes bored; the behavior of the game characters changes to accommodate the player’s affective state; or the game situation is changed to adapt to the player’s emotion (e.g., a shift to a less stressful ‘place’ within the game). Here, the player’s emotion is a key factor, actively manipulated to ensure engagement. This type of dynamic affective adaptation (affective feedback (Bersak, McDarby et al., 2001)) is the focus of current affective gaming efforts (Becker, Nakasone et al., 2005; Gilleade, Dix et al., 2005). I refer to these types of games affect-sensitive games. The games are capable of actively detecting, recognizing and adapting to (some of) the player’s affective states.

Finally, games can be developed for contexts that explicitly focus on affect. I refer to these as affect-centered games. Such games aim to train some affective skills; for example, emotional or social intelligence skills, such as recognition of emotion in self and others, learning coping strategies for negative emotions, such as re-appraisal, task-based problem-solving, and emotion regulation skills. Affect-centered games could also be used to help people in recognition of, and coping with, affective biases. For example, to recognize the anger-related hostility attribution bias, where hostility is attributed to someone whose behavior intereferes with one’s goals; or fear and anxiety-related biases, such as threat and self bias in perception. Such
games could be used to improve decision-making and perceptual skills. Affect-centered games could also be used as adjuncts in psychotherapy, to provide training and ‘homework exercises’, for highly-structured treatment protocols such as cognitive behavioral therapies; e.g., systematic de-sensitization. For a discussion of affect-centered games see Hudlicka (Hudlicka, 2009).

Note that while the ideal affective envelope for an educational game may be rather simple (e.g., to maintain arousal and valence at an optimal level to ensure engagement, to minimize boredom and frustration, to induce curiosity and satisfaction), an affective envelope for a therapeutic game is likely to be quite complex. Such games may even necessitate the induction of negative emotions, to provide opportunities for the player to experience some undesirable emotion, in order to learn how recognize and cope with its effects. These games would then enable an implementation of protocols such as systematic desensitization. Similarly, the affective gameplay profile for such games may include negative emotions, so that coping and regulation strategies for managing these emotions can be trained.

In affect-centered games, the player’s emotions are thus the central focus of the game; e.g., the achievement of a particular emotional state (e.g., happiness, pride) or the reduction of some undesirable state (e.g., fear, anger), or the induction of temporary negative state, for treatment purposes. Here the recognition of the players’ emotions is essential to support the selection of appropriate gameplay, either affect-adaptive or affect-inducing. To enable the induction of the desired emotions in the players, the non-playing characters in affect-centered games will need to be more affectively- and socially-realistic. This will require deeper models of emotion in the NPCs, as discussed in sections 4.3, 5 and 6.

The notions of affective envelope and affective profile are even more important in the affect-centered games, where affective states are not just a byproduct, or a mediating factor, of the learning or training experience, but where they play a central role.

Affect-Focused Game Design

Affect-sensitive games, but especially affect-centered games, thus require an explicit focus on emotion during game design and evaluation. The constructs introduced above, affective player profile, affective gameplay profile, and ideal affective envelope for player-game
interaction, provide the conceptual and representational structures that facilitate the central focus on player emotion during the game design process, and during the evaluation of the evolving game.

In addition to these constructs introduced above, which focus on the affective states of the players, we introduce another construct, which refers to game design in general: affect-focused game design. Affect-focused game design is an approach to game design that considers the student’s affective state as a critical element of the gameplay. The player’s emotion is thus not a side-effect of the game, which naturally occurs during the gameplay, and may at times include undesirable states, or states with undesirably high intensities. Rather, considerations of the player’s desired affective state, defined in terms of the affective profiles and envelopes, guide the design choices for all aspects of the game. This includes the gameplay structure (e.g., definition of, and transition among, different levels), recognition of player emotions and moods, and modeling and expression of emotions and moods by non-playing characters.

Other aspects of the game design are also influenced, most notably the visual and auditory aspects of the game, which also greatly influence the player’s affective state. Affect-inducing elements can be incorporated into multiple aspects of the game, including the look-and-feel and dynamics of the game environment, temporal and resource constraints on player behavior (e.g., requirements to complete a difficult task within a short timeframe designed to induce stress), choice of game tasks or situations provided to the player (e.g., easier tasks to build confidence, difficult task to challenge), and their integration within the overall plot or game narrative, as well as the appearance and behavior of the game characters or the players’ avatars.

A range of issues must therefore be addressed by the game designer. In game character development, the game designer should be clear about the following:

- What emotions, moods and personality traits should they express, when, and how?
- Are deep models of emotion necessary?
- Do the characters need to affectively respond to all situations or can their affective behavior be scripted to respond to selected game and user events?
- How realistic do the affective expressions need to be to make the game characters believable and maintain player engagement?
- Which expressive modalities should be used (e.g., speech tone and content, behavior selection, gestures, facial expressions)?
• Should the game characters’ behavior be directed to the player, other game characters or the game environment in general?

Regarding the affect-adaptive gameplay, the designer needs to be clear about the following:

• What role do the player’s emotions play in the overall gameplay (e.g., side effect of the game vs. central focus in therapeutic games)?

• Which player emotions or moods need to be recognized and which modalities and signals are most appropriate for their recognition (e.g., physiological signals, facial expressions, player behavior within the game)?

• Does the player’s personality need to be assessed?

• Which elements of the gameplay should be adapted (e.g., narrative and plot changes, game character behavior, game tasks)?

• What information about the player’s affective makeup is necessary to enable these adaptations?

The remainder of this chapter discusses how the emerging discipline of affective computing, and existing research in the affective sciences (psychology and neuroscience), help provide answers to these questions, and thereby support affect-focused game design.

The discussion emphasizes the modeling of emotion in game characters and affective user modeling, as these are critical for the development of educational and training games, and essential for affect-centered games (e.g., games for the training of affective and social skills, and psychotherapeutic games).

**Emotion Research Background**

Emotion research in the affective sciences over the past 20 years has produced data, conceptual and computational models, and methods and techniques that are directly relevant to affective game design, including the development of affective game engines. The emerging findings inform sensing and recognition of user emotions by machines, computational affective modeling, and the generation of expressive affective behaviors in non-playing characters.
Definitions and Terminology

When searching for a definition of emotions, it is interesting to note that many definitions describe instead characteristics of affective processing (e.g., fast, undifferentiated processing), or the roles and functions of emotions. The latter are usefully divided into those involved in interpersonal, social behavior (e.g., communication of intent, coordination of group behavior, attachment), and those involved in intrapsychic regulation, adaptive behavior, and motivation (e.g., goal management, coordination of multiple systems necessary for action, selection of best adaptive behaviors). Nevertheless, many emotion researchers do agree on a high-level definition of emotions. For purposes of modeling, emotions can thus be defined as: the evaluative judgments of the environment, the self and other social agents, in light of the agent’s goals and beliefs, and the associated distinct modes of functioning, reflected across multiple modalities (e.g., cognitive, physiological), and coordinating multiple subsystems (cognitive, behavioral), to achieve the agent’s goals.

Multiple Modalities

A key characteristic of emotions is their multi-modal nature, which has direct implications for both sensing and recognition of player emotion, and behavioral expression of emotions by game characters. The most visible is the behavioral / expressive modality; e.g., facial expressions, speech, gestures, posture, and behavioral choices. Closely related is the somatic / physiological modality: the neurophysiological substrate making behavior and cognition possible (e.g., neuroendocrine system manifestations, such as blood pressure and heart rate). The cognitive / interpretive modality is most directly associated with the evaluation-based definition of emotions above, and emphasized in the current cognitive appraisal theories of emotion generation. Finally, the experiential/subjective modality reflects the individual’s conscious, idiosyncratic experience of emotions.

Taxonomies of Affective States and Traits

The term ‘emotion’ can often be used rather loosely, to denote a wide variety of affective states, each with different implications for sensing and recognition, modeling and expression. A brief taxonomy of affective states is provided below, and their distinguishing features are
highlighted. *Emotions* proper represent short states (lasting seconds to minutes), reflecting a particular affective assessment of the state of self or the world, and associated behavioral tendencies and cognitive biases. Emotions can be further differentiated into basic and complex, the latter including the important set of social emotions, based on their cognitive complexity, the universality of triggering stimuli and behavioral manifestations, and the degree to which an explicit representation of the agent’s ‘self’ is required (Ekman and Davidson 1994; Lewis 1993). Basic emotions typically include fear, anger, joy, sadness, disgust, and surprise. Complex emotions such as guilt, pride, and shame have a much larger cognitive component and associated idiosyncracies in both their triggering elicitors and their behavioral manifestations, which makes both their detection and their expression more challenging. Moods reflect less-focused and longer lasting states (hours to days to months). Finally, affective personality traits represent more or less permanent affective tendencies (e.g., extraversion vs. introversion, aggressiveness, positive vs. negative emotionality). There are also many mixed states, with strong cognitive and affective components. Some of these were already mentioned above and are important in learning; e.g., confusion, engagement, flow. Examples of longer-lasting mixed states that are also important for learning are attitudes. For example, a student may have a generally positive or negative attitude towards a particular topic (e.g., algebra) or a particular mode of instruction (e.g., rote learning vs. learning involving more creative elements).

**Fundamental Processes of Emotions: Generation and Effects**

In spite of the progress in emotion research over the past 20 years, emotions remain an elusive phenomenon. While some underlying circuitry has been elucidated for some emotions (e.g., amygdala-mediated processing of threatening stimuli, the role of orbitofrontal cortex in emotion regulation), much remains unknown about the mechanisms of emotions. Given the multiple-modalities of emotion, the complexity of the cross-modal interactions, and the fact that affective processes exist at multiple levels of aggregation, it may therefore seem futile, at best, to speak of ‘fundamental processes of emotions’.

Nevertheless, for purposes of modeling emotions in game characters, as well as for the construction of affective user models, it is useful to divide emotions into two types of processes. Those responsible for the generation of emotions, and those which then mediate the effects of the activated emotions on cognition, expressive behavior (e.g., facial expressions, speech) and action
While multiple modalities play a role in emotion generation (Izard, 1993), most existing theories (and computational models) emphasize the role of cognition, both conscious and unconscious, in emotion generation. These are termed the ‘cognitive appraisal’ theories of emotion (Ortony, Clore et al., 1988; Roseman and Smith, 2001; Scherer, Schorr et al., 2001), and are the most relevant for the modeling of emotions in game characters. We therefore focus on cognitive appraisal theories when discussing models of emotion generation later in this chapter.

Central component of most cognitive appraisal theories is a set of domain-independent appraisal dimensions, which capture aspects of the current situation or event, and its relationship to the perceiving agent. These include novelty, urgency, likelihood, goal relevance and goal congruence, responsible agent, and the agent’s own ability to cope (Smith and Kirby, 2000; Ellsworth and Scherer, 2003). If the values of the dimensions can be determined, the resulting vector can be mapped onto the associated emotion space, defined by the appraisal dimensions, which provides a highly-differentiated set of possible emotions. (See figure 1).

![Figure 1: Emotion Generation via Cognitive Appraisal](image)

Less understood are the processes mediating the effects of the triggered emotions. The visible manifestations of specific emotions are certainly well documented, at least for the basic emotions; that is, the associated facial expressions, gestures, posture, nature of movement,
speech content and tone characteristics. The appraisal dimension theories mentioned above have also been used to explain emotion effects on expressive behavior, with suggestions that specific values of particular dimensions (e.g., novelty, goal congruence) map onto specific features of the different expressive modalities (e.g., novelty induces raised eyebrows and opening of the eyes in facial expressions (Scherer, 1992)).

The effects of specific emotions on behavior are also known, again, primarily for the basic emotions; e.g., running or hiding associated with fear, aggression associated with anger, withdrawal with sadness. There is, of course, a high degree of individual and cultural variability for the more complex emotions.

Some effects of emotions on cognition are also known; e.g., fear reduces attentional capacity and biases attention toward threat detection (Isen, 1993; Mineka, Rafael et al., 2003). However, the mechanisms mediating these observed effects have not yet been identified, although several theories have been proposed, including spreading activation (Derryberry, 1988; Bower, 1992), and parameter-based models. Proposed independently by a number of researchers (e.g., (Matthews and Harley, 1993; Hudlicka, 1998; Ritter and Avramides, 2000; Ortony, Norman et al., 2005), parameter-based models suggest that affective states act as global parameters, inducing patterns of variations in cognitive processes. Different patterns then characterize different emotions, in terms of systemic changes in biases, and processing speeds and capacities.

Recently, some researchers have suggested that the individual appraisal dimensions can also be a basis for developing models of emotion effect on cognition. Specific values of particular appraisal dimensions are thought to be associated with a specific cognitive manifestation. For example, a high-value of the appraisal dimension of certainty may be associated with heuristics and short-cuts, and ‘shallow’ processing in general, whereas a low value may be associated with deeper, analytical thought (Lerner and Tiedens 2006). The individual appraisal dimensions can thus play a role not only in mediating cognitive appraisal, but also in mediating the effects of emotions on both expression and cognition.

**Different Theoretical Views of Emotions**

Emotions represent complex, and often poorly understood, phenomena. It is therefore
not surprising that a number of distinct theories have evolved over time, to explain a specific subset of these phenomena, or to account for a particular subset of the observed data. Three of the most established theoretical perspectives, and those most relevant for computational affective modeling, are described below.

Discrete theories of emotions emphasize a small set of discrete or fundamental emotions. The underlying assumption of this approach is that these fundamental, discrete emotions are mediated by associated neural circuitry, with a large innate, ‘hardwired’ component. Different emotions are then characterized by stable patterns of triggers, behavioral expression, and associated distinct subjective experiences. The emotions addressed by these theories are typically the ‘basic’ emotions; joy, sadness, fear, anger, and disgust. Because of its emphasis on discrete categories of states, this approach is also termed the categorical approach (Panskepp, 1998). For modeling purposes, the ‘semantic primitives’ representing emotions in models would be the basic emotions themselves.

An alternative method of characterizing affective states is in terms of a small set of underlying factors, or dimensions, that define a space within which distinct emotions can be located. This dimensional perspective describes emotions in terms of two- or three-dimensions. The most frequent dimensional characterization of emotions uses two dimensions: valence and arousal. Valence reflects a positive or negative evaluation, and the associated felt state of pleasure vs. displeasure, as outlined in the context of undifferentiated affect above. Arousal reflects a general degree of intensity or activation of the organism. The degree of arousal reflects a general readiness to act: low arousal is associated with less energy, high arousal with more energy. Since this 2-dimensional space cannot easily differentiate among emotions that share the same values of arousal and valence, e.g., anger and fear, both characterized by high arousal and negative valence, a third dimension is often added. This is variously termed dominance or stance. The resulting 3-dimensional space is often referred to as the PAD space (Mehrabian, 1995) (pleasure (same as valence), arousal and dominance). The representational semantic primitives within this theoretical perspective are thus the 2 or 3 dimensions.

The third view emphasizes the distinct components of emotions, and is often termed the componential perspective (Leventhal and Scherer, 1987). The ‘components’ referred to in this view are both the distinct modalities of emotions (e.g., cognitive, physiological, behavioral,
subjective) and also the components of the cognitive appraisal process. These are referred to as appraisal dimensions or appraisal variables. A stimulus, whether real or imagined, is analyzed in terms of its meaning and consequences for the agent, to determine the affective reaction. Several sets of appraisal variables have been proposed by different researchers, with the most comprehensive set proposed by Scherer, and consisting of the following: novelty (is the stimulus new), valence (is it inherently pleasant or unpleasant), goal relevance (does it represent a situation or event relevant to the agent’s goals), responsible agent (who is responsible for the event or situation, and was it intentional or accidental), goal congruence (will the situation or event help or hinder the agent’s goals), coping potential (what can the agent do about the situation or event), and norms and values (is the situation or event consistent with the agent’s internal and cultural norms). Once the values of these dimensions are determined by the organism’s evaluative processes, the resulting vector is mapped onto a particular emotion, within the n-dimensional space defined by the appraisal dimensions. The semantic primitives for representing emotions within this model are thus the individual appraisal dimensions.

Although generally not classified as a componential theory, the cognitive appraisal theory developed by Ortony and colleagues (Ortony, Clore et al., 1988), referred to as the OCC model, also offers a set of domain-independent evaluative features (e.g., desirability, goal congruence). The OCC model was the first computation-friendly theory of emotion generation, and is the most frequently implemented theory of cognitive appraisal in computational models of emotion.

It must be emphasized that these theoretical perspectives should not be viewed as competing for a single ground truth, but rather as distinct perspectives, each arising from a particular research tradition (e.g., biological vs. social psychology), focusing on different sets of affective phenomena, considering distinct levels of resolution and fundamental components (e.g., emotions as distinct primitives vs. appraisal dimensions as distinct primitives), and using different experimental methods (e.g., factor analysis of self-report data vs. neuroanatomical evidence for distinct processing pathways). The different perspectives also provide different degrees of support for the distinct processes of emotion; e.g., the componential theories provide extensive details about cognitive appraisal.

Until such time as emotions are fully understood and explained, it is best to view these theories as alternative explanations, each with its own set of explanatory powers and scope, and
supporting data, analogously, perhaps, to the wave vs. particle theory of light, as suggested by Picard (Picard 1997).

Affective Gaming

Affective gaming has received much attention lately, as the gaming community recognizes the importance of affect in the development of more engaging games (Sykes 2004; Gilleade, Dix et al., 2005). Affect plays a key role in the user experience, in entertainment, but especially in ‘serious’ games, developed for education, training, assessment, therapy or rehabilitation – that is, in the affect-sensitive and affect-centered games discussed above.

Current focus in affective gaming is primarily on the sensing and recognition of the players’ emotions, and on tailoring the game responses to these emotions (Sykes and Brown, 2003; Gilleade and Dix, 2004). Progress is being made in emotion recognition in games, primarily in the recognition of arousal (a component of emotion), and several games have been developed in laboratories exploring the possibility of adapting the gameplay to the player’s state; e.g., changing the difficulty of the levels or the reward structure if the player becomes too frustrated or bored (Becker, Nakasone et al., 2005; Gilleade, Dix et al., 2005).

A significant effort is also being devoted to generating ‘affective behaviors’ in the game characters, to enhance their realism and believability. This is made possible by the increasing sophistication of graphical techniques available for real-time rendering of the characters’ expressive features, primarily facial expressions.

Less emphasis is placed on explicit models of emotions in game characters, both the dynamic generation of emotions in real time, and the modeling of their effects on the characters’ expressive behavior, actions within the game, and emotion effects on the characters’ perceptual and decision-making processes (Hudlicka, 2008).

Gilleade and colleagues captured the objectives of affective gaming in a succinct statement, describing a progression of functionalities an affective game should support: “Assist me, Challenge me, Emote me” (Gilleade, Dix et al., 2005). The last goal represents the type of enhanced engagement, perhaps even the induction of specific emotions, discussed above, in the
In this chapter I suggest that advancing the state-of-the-art in gaming to effectively cover the “assist me, challenge me, emote me” spectrum will require increased emphasis on explicit models of emotions in non-playing characters, as well as the development tools that directly support such models, such as the affective game engine discussed in section 7.

Affective Computing

Affective computing is a cross-disciplinary research and practice area that has been growing and evolving over the past 15 years. The term affective computing was coined by Picard in the eponymous book published in 1997 (Picard, 1997). Picard defined affective computing as “computing that relates to, arises from, or deliberately influences emotions” (Picard, 1997, p. 3).

Affective computing can be divided into four core areas: emotion sensing and recognition by machines; affective models of users; computational models of emotion and cognitive-affective agent architectures, and emotion expression in synthetic agents and robots. All of these areas are directly relevant to affective gaming, and for the development of educational and training games. Affective computing is of course even more relevant for affect-centered games, where inducing appropriate emotional states in the players, and adaptation to players’ affective states, are essential.

The methods and techniques developed in the core areas of affective computing are directly applicable to the design of educational and training games, and especially relevant for the design of affect-centered games, such as therapeutic games. These four areas of affective computing are briefly introduced below.

Recognition of Emotion by Machines

Much progress has been made in machine recognition of emotion over the past 5 years. Multi-modal approaches (facial expression, speech and physiological signals) are beginning to approach the accuracy rates of human observers (Pantic and Bartlett, 2007; Gunes, Piccardi et al., 2008). Significant advances are also being made in recognizing spontaneous emotion expressions, under more realistic circumstances (i.e., in real-life vs. controlled laboratory
settings) (Zeng, Pantic et al., 2009), and attempts are being made to recognize more complex emotions, such as embarrassment (Cohn, Ambadar et al., 2005).

While impressive, these results don’t translate into similar accuracy rates in more naturalistic settings, such as those required in gaming. In fact, accurate recognition of spontaneous emotions, in naturalistic settings, where the expressive manifestations of emotions are more subtle and have more variability, where the emotions are not limited to the basic emotions, and where the sensor data are noisy and incomplete, remains a major challenge in machine recognition of emotion (Zeng, Pantic et al., 2009).

Emotion recognition is best understood as a classification problem, where features extracted from the sensed data are mapped onto the categories of emotions to be recognized.

The major components of the emotion recognition process are therefore as follows:

• Obtain accurate signals that are most diagnostic of specific emotions.
• Identify most useful features within these signals to use as input into the classification algorithms.
• Select the most appropriate classification algorithm to obtain the best results.

The multi-modal nature of emotions, and their evolution over time, both facilitate and constrain recognition of emotions in players. Many emotions have characteristic multi-feature, multi-modal ‘signatures’ that serve as basis for both recognition and expression. For example, fear is characterized by raising of the eyebrows (facial expression), fast tempo and higher pitch (speech), threat bias in attention and perception (cognition), a range of physiological responses reflecting increased arousal and mobilizing the energy required for fast reactions, and, of course, characteristic behavior (flee vs. freeze). Identifying unique emotion signatures that provide the highly diagnostic signals necessary for recognition is a key challenge in machine emotion recognition. Once identified, the constituent features guide the selection of appropriate (non-intrusive) sensors, and the classification algorithms required to map the raw data onto a recognized emotion.

Recognition rates then depend greatly on the modality and channels used, on the quality of the sensed data, the feature sets used as input to the classification algorithm, and the classification algorithm itself. Increasingly, multi-modal approaches are being used, primarily visual (facial expression) and audio (speech content and prosody), to identify emotions. Physiological signals are also being incorporated to increase recognition accuracy, primarily
signals reflecting the activity of the autonomic nervous systems. Contextual variables (e.g., state of the game) can also help to increase recognition rates.

However, not all of these promising results readily translate to the gaming context. Gaming presents a specific set of constraints and challenges for the recognition and expression of emotions. Broad game categories (e.g., entertainment vs. serious gaming), game genres (e.g., FPS vs. slower-tempo strategy games vs. games emphasizing social interaction, such as Sims), and delivery modes ranging from the Wii to iPhones, have different requirements for both the types of emotions that may need to be sensed and expressed, and the most appropriate channels and sensors for doing so.

**Affective User Modeling**

A key element in successful emotion recognition, and in adaptation to user emotion, is an affective model of the user. Affective user models are analogous to the traditional cognitive user models, used in learning and tutoring systems. However, as the name implies, affective user models are augmented to also include affective information about the user: a type of an affective user profile. Affective user modeling is concerned with the construction of such models, and affective adaptation addresses the ways in which a computer system, most often a learning or a training system, can then adapt to the user’s emotional states.

Traditional ‘cognitive’ user models focus on representing the user’s knowledge state, beliefs, preferences, general characteristics (e.g., age, gender, skill level), goals, plans, and, in learning environments, possible misconceptions about the domain of interest (Martinho, Machado et al., 2000). In contrast, an affective user model contains data about the types of emotions the user is likely to experience in a given human-machine context, and how those emotions are manifested by the user, within the modalities the system can sense. Such models can then be used as basis for emotion recognition, and to support affect-adaptive gameplay, by supporting reasoning about the likely triggers for particular user emotions (Hudlicka and McNeese, 2002).

Affective user models are thus representational structures that store information about the player’s affective profile, and play a critical role in affect-adaptive gaming, supporting both emotion recognition, and the development of appropriate affect-adaptive strategy by the game
system. Since affective behavior can be highly idiosyncratic, affective models necessarily involve a learning component. These components enable the identification of characteristic affective patterns, extracted from player state and gameplay interaction, by tracking player’s behavior over time. For example, Player A may express frustration by more forceful manipulation of the game controls, whereas Player B may exhibit increasing delays between game inputs.

Significant existing research in intelligent tutoring systems provides the knowledge and methods supporting affective user modeling (e.g., (D’Mello, Craig et al., 2008; Forbes-Riley, Rotaru et al., 2008; McQuiggan, Mott et al., 2008; Yannakakis, Hallam et al., 2008). This includes sensors and classification algorithms for identifying specific emotions that are relevant for both intelligent tutoring and gaming (e.g., frustration, interest, boredom, engagement) with reasonable rates of accuracy (70-80%). The algorithms used to associate specific user manifestations (e.g., increased heart rate, frown, speech quality) or user-system interaction patterns (e.g., type of input), with specific emotions range from simple correlations and multiple regression models (Witten and Frank, 2005; Forbes-Riley, Rotaru et al., 2008), to machine learning algorithms, both symbolic and connectionist, including tree induction algorithms and artificial neural nets (D’Mello, Craig et al., 2008). Many of these algorithms are available in the Waikato Environment for Knowledge Analysis (Witten and Frank, 2005).

Since affective user models are typically used in learning systems, other learning-relevant states are often of interest, in addition to emotions proper. These include boredom, uncertainty, confusion, interest, and flow (Carberry and de Rosis, 2008; D’Mello, Craig et al., 2008). Thus, for example, in a learning system which can detect boredom, frustration, and surprise, and tries to maintain an optimal level of engagement, the following information might be contained in an affective user model: signatures of boredom, frustration, surprise, interest, and a neutral state, in terms of the sensed channels (e.g., heart rate, galvanic skin response, mouse pressure); specific triggers in the user-system interactions that precede and follow each state (e.g., frustration occurs when user is unable to solve 2 tasks in a row, interest occurs when new information is presented to the user within his/her range of understanding); and user behavior when a specific state is entered (e.g., user stops working on a task when bored; makes mistakes when frustrated).

As discussed above, emotions are manifested along a number of expressive channels, including facial expressions, speech, physiological signals, posture, gestures, body movements,
and, of course, actual behavioral choices. Any of these can potentially be sources of data for the construction of an affective user model.

Affective user models vary in the depth of the user’s mental apparatus represented. They can be ‘black box’ models, where only the input-output patterns of the user’s affective profile are represented.

For example, a black-box style affective user model might simply contain pairs of the form \{<triggers><emotion>\} and \{<emotion>,<behavior>\}, such as:

\[
\{\text{loss of points | unable to reach game goal | character dies}, \text{frustration}\} \\
\{\text{frustration,} \\
\{\text{> 1 minute lag in input | mouse pressure > x | inputs insulting comments to computer system}}\}
\]

and use these to support both emotion recognition (from user behavior), and the development of adaptive strategies (by using data about what system behavior or user-system interactions trigger which user emotions).

Alternatively, affective user models can attempt to reconstruct the user’s mental apparatus, including internal constructs such as beliefs, expectations, goals, and plans, and attempt to simulate the user’s actual cognitive-affective processing, within the context of the specific gameplay. Such models then provide ‘deeper’ representation of the user’s mental architecture. In other words, the affective user model may try to simulate the user’s own appraisal of the on-going situation, and infer his/her goals and beliefs. Such models then begin to resemble cognitive-affective architectures, and may be capable of simulating some of the user’s own cognitive / affective processing; e.g., the cognitive appraisal processes resulting in a particular emotion.

**Emotion Modeling and Cognitive-Affective Architectures**

A number of computational emotion models have been developed for both research and applied purposes. These models typically focus on the basic emotions (e.g., joy, fear, anger, sadness), and use a variety of methods for implementing emotion generation via appraisal (Bates, Loyall et al., 1992; Andre, Klesen et al., 2000; Broekens and DeGroot, 2006; Reilly, 2006), or, less frequently, emotion effects on cognition, via parametric modeling (Hudlicka, 1998; Ritter and Avramides, 2000; Hudlicka, 2007; Hudlicka, 2008).
Models used as part of agent architectures also include the modeling of emotion effects on expressive behavior and action selection. These are typically implemented via direct mapping of a particular emotion onto specific behavior, or patterns of expression along one or more modalities; e.g., If ‘happy’ then ‘jump’ and ‘smile’. Some models implement a mapping onto components of expressive behaviors, rather than fully-formed expressions; e.g., mapping values of individual appraisal dimensions onto elements of facial expressions, such as eye brow position (Scherer, 1992).

Most models of emotion focus on emotion generation, typically using cognitive appraisal. Most of these appraisal models are based on either the OCC model (Ortony, Clore et al., 1988), or the explicit appraisal dimension theories developed by (Smith and Kirby 2000; Scherer, Schorr et al., 2001) (e.g., novelty, valence, goal relevance and congruence, responsible agent, coping potential). Typically, symbolic AI methods are used to implement the stimulus-to-emotion mapping, whether this is done via an intervening set of appraisal dimensions, or directly from the domain stimuli to the emotions. In general, the complexity of this process lies in analyzing the domain stimuli (e.g., features of a game situation, behavior of game characters, player behavior) and extracting the appraisal dimension values. This may require representation of complex mental structures, including the game characters’ and players’ goals, plans, beliefs and values, their current assessment of the evolving game situation, and expectations of future developments, as well as complex causal representation of the gameplay dynamics. Rules, semantic nets and Bayesian belief nets are some of the frequently used formalisms implementing this mapping.

**Emotion Expression in Game Characters**

The expression of emotions in synthetic agents and robots, and game characters, requires two distinct components, with associated distinct methods and technologies. The agent must not only depict the emotion in an appropriate manner, along its available expressive channels (e.g., face, speech, movement), appropriately synchronized, and depicting realistic affective dynamics, but it must also display an appropriate emotion for the specific context. Achieving these goals involves very different sets of methods and technologies, with the former closely linked to computer graphics (rendering and animation technologies) and robotics, and the latter involving
emotion models and agent architectures, discussed above.

A critical factor in emotion expression of emotion is the identification of a set of semantic primitives for each expressive channel, whose distinct configurations characterize the different emotions (Hudlicka, 2005). An appropriate set of such primitives greatly facilitates both recognition and expression, by providing a unifying vocabulary of features. The most established example of such a vocabulary is the Facial Action Coding System (FACS) developed by Ekman and Friesen (1978). FACS describes in detail features such as shape of the lips and eyebrows, narrowing of the eyes, and raising of cheeks, to completely define a broad range of facial expressions. Specific configurations of these expressions then characterize different emotions; e.g., lips turned upward, raising of lower eyelid and narrowing of lids are associated with happiness. FACS has been successfully used to model facial expressions in synthetic characters. Semantic primitives for other modalities are also being developed, including speech (patterns of pitch and tonal variations used to identify basic emotions (Petrushin, 2000), and posture (‘basic posture units’ identified by Mota and Picard (Mota and Picard, 2004), used to identify boredom and engagement).

The semantic primitives then facilitate affective expression generation, by helping define the syntax and semantics of markup languages used to specify the expressive features of emotions, across different channels (face, body movement, speech) (Prendinger and Ishizuka, 2004). The identification of the most diagnostic emotion features also guides the selection of best expressive channels to convey a particular emotion to the player, via game character behavior. In emotion expression, multiple modalities also present a challenge, by requiring that expression be coordinated and synchronized across multiple channels, to ensure character realism. For example, expression of anger must involve consistent signals in speech, movement and gesture quality, facial expression, body posture and specific action selection, evolving, and decaying, at appropriate rates.

Requirements for Developing Affect-Sensitive and Affect-Centered Games

To develop affect-sensitive and affect-centered games, all four of the categories of functionalities discussed above must be included.
Recognition of Player Emotions

The game needs to be able to recognize the player’s emotions. Which emotions need to be recognized and which sensors are most appropriate, depends on the game and its context. For some games, it may be adequate to recognize levels of arousal and infer the associated emotion. This is relatively easy from physiological measures such as galvanic skin response or heart rate, and advances in non-intrusive sensors make detection of arousal increasingly feasible. To identify a specific emotion, an assessment of valence is also needed. This is more challenging, typically requiring machine vision or facial EMG, to detect the position and movement of facial muscles. Again, recent advances in EEG and other physiological sensors may make non-intrusive valence detection possible in the near future. Multimodal sensors are almost essential to achieve the desired accuracy. In gaming, there is the associated requirement for non-intrusive sensors. To this end, researchers have explored signals such as the manner in which players manipulate the game controls, to detect their affective state.

Affective Models of Players

The player’s affective profile is essential for emotion recognition, and provides a basis for constructing a detailed affective user model. Such a model then supports both the recognition of player emotion, but also the selection of appropriate gameplay strategies, to adapt to the player’s affective state. In affect-centered games, an affective user model allows the game to implement the best protocol for inducing specific emotion in the player, to achieve the game objectives. For example, to induce an emotion to allow the player to experience a particular affective bias, or to experience a negative emotion, for purposes of systematic desensitization in psychotherapeutic games.

Modeling Emotions in Non-Playing Characters

The more affectively and socially realistic the non-playing game characters are, the more effective the game can be in engaging the player, and in inducing the desired emotions in the player. To achieve these goals, the game characters need to have underlying models of emotion. Such models enable them to dynamically react to evolving game situations, or player-game
interactions, and generate appropriate emotions in real-time. The NPCs in affect-sensitive and affect-centered games therefore need to have the capabilities to model emotion. This means modeling both emotion generation, and emotion effects on behavior and cognition. Emotion generation models are based on stimuli representing situations in the gameplay (e.g., behavior of another NPC, changes in the game environment, or player activity), and the characters’ own internal goals and needs. Emotion effects models map the generated emotions onto their effects on cognition (affective biases), expressive behavior (e.g., facial expressions), and specific behavioral choices (e.g., approach vs. withdraw).

The NPC emotion models may or may not need explicit models of the emotions on cognition. Such models provide additional richness and flexibility, and provide an efficient way to generate variability in behavior, thereby making the characters seem more lifelike. However, not all games require this type of complexity, and mapping emotions directly onto expressive behavior and action selection is often adequate.

Expression of Emotions by Non-Playing Characters

Finally, the NPCs should be able to express their emotions in a manner appropriate for the game context. This means selecting the most appropriate emotion-specific expressive behavior (e.g., smile, laugh, growl, etc.), and selecting a specific action that reflects the emotion (e.g., dance, hop and up and, attack, etc.). The specific choices depend on the deployment platform (e.g., a high-resolution large screen vs. an iPhone), and the modalities available for the character. For example, a low-resolution image on a mobile device, such as the iPhone, may make it difficult to express emotions via facial expressions, and may require instead displaying the emotion via body movements. Much progress has been made in the graphical support necessary to effectively convey realistic affective expression, and research in affective computing and social agents has much to contribute to emotion expression by NPCs.

Some of the affective computing methods for the sensing, recognition and expression of emotion are being explored in affective gaming (Sykes and Brown 2003). However, the area of affective user modeling and computational models of affect has, until very recently, been largely ignored (Hudlicka, 2008; Hudlicka and Broekens, 2009; Broekens and Hudlicka, 2010). The remainder of this chapter therefore emphasizes the importance of affective modeling, as a basis for more realistic behavior of game characters, and as a means of developing more realistic and
complete affective models of the players. Both of these are necessary to support the design of and development of affect-sensitive and affect-centered educational, training and therapeutic games.

Methods for Modeling Emotions in Game Characters and Player Models

The complexity of models required to generate affective behavior in game characters varies with the complexity of the game plot, the characters, the available behavior repertoire of the player within the game, and of course the game objectives (e.g., entertainment vs. education vs. therapy). For many games, simple models are adequate. In these models, a small set of gameplay or player behavior features is mapped onto a limited set of game characters’ emotions, which are then depicted in terms of simple manipulations of character features; e.g., player fails to find a treasure and the avatar shows a ‘sad face’, player loses to a game character and the character gloats (Broekens and Hudlicka, 2009; Hudlicka, and Broekens, 2009). Such simple models are termed ‘black-box’ models, since they make no attempt to represent the underlying affective mechanisms. Data available from the affective sciences provide the basis for defining the necessary mappings (triggers-to-emotions, emotions-to-effects). However, as the complexity of the games increases, the need for more sophisticated affective modeling arises. This is due to more complex plots and narratives, and associated increase in the sophistication of the game characters, and richness of player interactions. This may require more complex ‘process-models’, which use explicit representations of some of the affective mechanisms, and allow a greater degree of generality and complexity.

In an effort to establish more systematic guidelines for affective model development, and to facilitate analysis of existing models, Hudlicka has recently suggested dividing the modeling processes into those responsible for emotion generation, and those responsible for implementing emotion effects (Hudlicka 2008a; 2008b). Each of these broad categories of processes are further divided into their constituent computational tasks. These computational tasks then serve as the building blocks for modeling the high-level affective processes.

For emotion generation, these computational tasks include defining the following:

- stimulus-to-emotion mapping;
- nature of the emotion dynamics; i.e., functions defining the emotion intensity calculation, and
the ramp-up and decay of the emotion intensity over time; and

- methods for combining multiple emotions, necessary for combining existing emotions with newly derived emotions, and for selecting the most appropriate emotion when multiple emotions are generated.

For emotion effects, these computational tasks include defining the following:

- emotion-to-cognitive process mappings, to capture affective biases on cognition;
- emotion-to-behavior mappings, to capture emotion effects on expressive behavior and behavioral choices;
- magnitude of the associated effects on each affected process, and the dynamics of these effects; and
- methods for integration of the effects of multiple emotions, both in cases where a residual effect of a prior emotion is still in force, and in cases where multiple emotions are generated simultaneously, and their effects on cognition and behavior must be integrated.

Approaches to modeling these processes are discussed below.

**Modeling Emotion Generation**

Our understanding of emotion generation is best within the cognitive modality and most existing models of emotion generation implement *cognitive appraisal*, which is best suited for affective modeling in gaming. The discussion below is therefore limited to these theories and models.

Many researchers have contributed to the current versions of cognitive appraisal theories (Arnold, 1960; Lazarus, 1984; Mandler, 1984; Frijda, 1986; Roseman and Smith, 2001; Scherer, Schorr et al., 2001; Smith and Kirby, 2001). Most existing computational models of appraisal are based on either the OCC model (Ortony, Clore et al., 1988), or the explicit appraisal dimension theories developed by (Smith and Kirby, 2000; Scherer, Schorr et al., 2001), and outlined in section 3 above (e.g., novelty, valence, goal relevance, goal congruence, responsible agent, coping potential).

A number of computational appraisal models have been developed for both research and applied purposes (e.g., (Bates, Loyall et al., 1992; Andre, Klesen et al., 2000; Reilly, 2006). These models typically focus on the basic emotions (e.g., joy, fear, anger, sadness), and use a
variety of methods for implementing a subset of the computational tasks outlined above. Most frequently, symbolic methods from artificial intelligence are used to implement the stimulus-to-emotion mapping, whether this is done via an intervening set of appraisal dimensions, or directly from the domain stimuli to the emotions.

In general, the complexity of this process lies in analyzing the domain stimuli (e.g., features of a game situation, behavior of game characters, player behavior), to evaluate their significance for the NPC, and enable the generation of a particular emotion. In situations where domain-independent appraisal dimensions are used, the emotion generation process consists of two phases. First, the domain stimuli are analyzed to determine the values of the different appraisal dimensions (e.g., Is it new? Is it conducive to the NPC’s goals? Who is responsible for it?). This analysis is likely to require the representation of a set of complex mental structures, including the game characters’ and players’ goals, plans, beliefs and values, their current assessment of the evolving game situation, and expectations of future developments, as well as complex causal representation of the gameplay dynamics. Rules, semantic nets and Bayesian belief nets are some of the most frequently used formalisms to implement this mapping. Next, the vector of appraisal dimensions is mapped onto the space of possible emotions, defined by the appraisal dimensions. This is typically done by designating certain regions within the n-dimensional emotion space as corresponding to specific emotions, and then identifying the emotion that is nearest the point represented by the appraisal vector. To determine closeness, some suitable measure of distance is then used, for example, Euclidean distance. The high-dimensionality of the space defined by the appraisal dimensions allows a high-degree of differentiation of affective states, e.g., delineating emotions of different intensity, from mild annoyance, through frustration, to anger and rage.

Emotion dynamics are generally limited to calculating emotion intensity, which is usually a relatively simple function of a limited set of the appraisal dimensions (e.g., absolute value of the desirability of an event or a situation multiplied by its likelihood (Reilly, 2006)), or some customized quantification of selected feature(s) of the stimuli (e.g., a linear combination of weighted factors that contribute to each emotion of interest).

The ramp-up and decay of emotion intensity may not be modeled at all, with the emotion simply appearing in its full intensity, lasting for some time interval, and then returning to zero or its baseline value for that character. Alternatively, the ramp-up and decay rates may follow some
monotonically increasing or decreasing (respectively) function, to model the affective dynamics in a more realistic manner. A variety of functions have been used in appraisal models, including linear, exponential, sigmoid and logarithmic (Reilly, 2006; Hudlicka, 2008). In general, the theories and conceptual models developed by psychologists do not provide sufficient information to generate computational models of affective dynamics, and educated guesswork and model tuning are required during this phase of affective modeling.

The issue of integrating multiple emotions is the most neglected, both in existing psychological theories and conceptual models, and in computational models. Typically, very simple approaches are used to address this complex problem, which limits the realism of the resulting models in any but the most simple situations. In general, intensities of synergistic emotions (e.g., all positive or all negative emotions) are combined via a simple sum, average, or max functions. Recently, problems associated with these simple functions have been identified (Reilly, 2006), and other approaches have been suggested, including logarithmic and sigmoid functions (Reilly, 2006; Picard, 1997). In some cases, customized, domain-dependent weightings are used, so that a particular emotion is preferentially generated, as a function of the character’s personality. For example, high-extraversion characters may be more likely to feel positive emotions, whereas high-neuroticism characters may be more likely to feel negative emotions (Hudlicka, 2007). A more problematic situation occurs when opposing or distinctly different emotions are derived (e.g., a particular situation brings both joy and sadness). Neither the available theories, nor existing empirical data, currently provide a basis for a principled approach to this problem. The computational solutions are therefore generally task- or domain-specific, and often ad hoc.

Modeling Emotion Effects

For modeling purposes, it is useful to divide emotion effects into two categories: the visible, often dramatic, behavioral expressions, and the internal, but no less dramatic, effects on attention, perception and cognition. The majority of existing models of emotion effects focus on the former. While technically challenging, the behavioral effects are easier from a modeling perspective. This is due to the large body of empirical data regarding the visible manifestations of particular emotions, and the established techniques for 3D dynamic graphical modeling and rendering required to display these expressions in virtual characters. We know, in general, how the basic emotions are expressed in terms of facial expressions, quality of movement and gestures, quality of speech, and behavioral choices. As with emotion generation, the degree of
variability and complexity increases as we move from the fundamental emotions such as fear, joy, anger, to the more cognitively-complex emotions such as pride, shame, jealousy. The focus here will be on cognitive effects only. This is due in part to space limitations, but primarily because such models have been neglected in the emotion modeling literature, and are relevant for modeling emotions in NPCs in affect-sensitive and affect-centered games.

The internal effects that emotions exert on the perceptual and cognitive processes that mediate adaptive, intelligent behavior are less understood than those involved in emotion generation. This is true both for the fundamental processes (attention, working memory, long-term memory recall and encoding), and for higher-level processes such as situation assessment, problem-solving, goal management, decision-making, and learning. These processes are generally not modeled in existing game characters, and, indeed, may not be necessary. However, as the affective complexity of games increases, the need for these types of models will emerge. This is particularly the case in affect-centered games, where the assessment and triggering of specific emotions is the focus. For example, in games designed to support cognitive-behavioral therapies, and the associated cognitive restructuring, an ability to model the processes mediating affective biases would require explicit modeling of emotion effects on distinct perceptual and cognitive processes.

While data are available regarding some of the emotion effects on cognition (see section 3), the mechanisms of these processes have not been identified. This presents challenges for the modeler, frequently resulting in black-box models rather than mechanism-based process models. Nevertheless, several recent efforts focus on process-models of emotion effects on cognition, most often in terms of parametric-modification of cognitive processes (e.g., (Hudlicka, 2003; Belavkin and Ritter, 2004; Hudlicka, 2007; Ritter, Reifers et al., 2007; Sehaba, Sabouret et al., 2007)). For example, Hudlicka’s MAMID model uses a series of parameters to control processing within individual modules in a cognitive-affective architecture, enabling the implementation of the observed emotion effects, such as speed and capacity changes in attention and working memory, as well as the implementation of specific biases in processing (e.g., threat and self-focus bias in anxiety). Several models of emotion effects on behavior selection use a decision-theoretic formalism, where emotions bias the utilities and weights assigned to different behaviors (Lisetti and Gmytrasiewicz, 2002; Busemeyer, Dimperio et al., 2007).

Modeling the magnitude and dynamics of emotion effect is problematic, as it requires
going beyond the qualitative relationships typically available from empirical studies (e.g., anxiety biases attention towards threatening stimuli). In the majority of existing models, quantification of the available qualitative data is therefore more or less ad hoc, typically involving some type of linear combinations of the weighted factors, and requiring significant fine-tuning to adjust model performance. The same is true for modeling the integration of multiple emotions. Especially challenging for both of these tasks is the lack of data regarding the internal processes and structures (e.g., effects on goal prioritization, expectation generation, planning). The difficulties associated with characterizing these highly internal and transient states may indeed provide a limiting factor for process-level computational models of these phenomena.

The next section discusses how some of the techniques outlined above could be incorporated into a tool that would facilitate the development of affect-sensitive and affect-centered games: an affective game engine.

**Affective Game Engines**

Progress in gaming has been greatly aided by the emergence of game engines: development tools that facilitate the creation of games by providing realistic graphics and real-time simulation environments. Game engines exist for many game genres (e.g., FPS vs. serious games for training), and vary in complexity and cost (from the free Crystal Space, engines such as Unity (around USD200) to the popular Unreal engine (~USD300,000)) (Stang, 2003). However, to date, no engine has emerged that focuses explicitly on facilitating the development of affectively realistic game characters and avatars, and suitable for the development of affect-sensitive and affect-centered games. Availability of a high-level development tool, that would provide the primitives necessary to support development of affect-sensitive and affect-centered games, would greatly contribute to advancing the state-of-the-art in this area. Some requirements for such a game engine are discussed below, in terms of the theories and methods offered by affective computing and affective modeling.

What types of capabilities would such an affective game engine need to have? To support the development of affect-sensitive games, the affective game engine would need to: (1) facilitate recognition of a broad range of player’s emotions, in real-time, and within varied gaming
contexts (e.g., from the Wii to iPhones); and (2) generate effective adaptations to these emotions, including changes in gameplay reward structure, and realistic portrayal of appropriate emotions by the game characters. To enable this type of emotion recognition and adaptation, the game engine would need to support the dynamic construction of an affective user model (Hudlicka and McNeese, 2002; Carberry and de Rosis, 2008); that is, a model of the user that contains information not only about his/her current level, skills, knowledge state, and game history, but also about the emotions typically experienced, their characteristic expression and behavioral manifestations, their triggers, and typical transitions among them.

To support the development of socially complex and affectively realistic games, the game engine would need to support the development of game characters capable of recognizing emotions in other game characters, and dynamically generating appropriate and affectively-realistic behavior. For example, one can imagine a next-generation of Sims, where the characters have sufficient affective complexity to react with pride, jealousy or embarrassment to some social situation. They could then realistically display the associated affective manifestations, across multiple modalities; e.g., facial expressions, head movement, hand gestures, gaze. To accomplish such level of realism, the game characters would need to incorporate a computational model of emotion. Such an emotion model would need to dynamically generate emotions, in real-time, in response to evolving gameplay, including the behavior of the player and the other game characters. The model would also need to model the effects of these emotions on the character’s decision-making and behavior, the latter including both affective expression (e.g., changes in facial expressions, gestures and quality of movement), as well as specific emotion-dependent behavioral choices (e.g., run or hide when fearful, approach when happy or helpful; attack when aggressive). The game engine would also need to support the development of affectively-realistic player avatars, capable of displaying the player’s affective state in a manner consistent with the player’s own expectations and needs.

The primary contributions to the development of an affective game engine would come from affective computing (Hudlicka, 2008), as discussed above. A number of specific requirements emerge for an affective game engine. These include a central knowledge-base, containing basic information about emotions in general, the affective profiles of both the player and the game characters, and representations of the currently active affective states, for both the player and the game characters (see figure 2). The knowledge and data represented in this
centralized information repository would be shared by the modules implementing the four core functionalities of an affective game engine: emotion recognition in the player, emotion expression by game characters and player avatars, representation of the player’s emotions via dynamic affective user models, and modeling of emotions within the game characters.

Figure 2: Role of a Centralized Emotion Knowledge-Base in the Proposed Affective Game Engine

The affective game engine would also provide templates and representational primitives to support the development of affective models of the player, and the structures discussed above, to facilitate the design and evaluation of affect-centered games: affective player profile, affective gameplay profile, and an ideal affective envelope of the player during the training or therapeutic gameplay.

The affective game engine would provide support for modeling both the emotion generation in game characters, and the subsequent effects of these emotions on the internal ‘cognitive’ processes within the NPCs’ architecture, as well as their expressive behavior and actions in the game environment. The engine would offer alternatives for emotion generation in terms of either direct mapping of gameplay stimuli onto emotions, mappings via intervening appraisal dimensions, or via the 2 or 3 dimensions comprising the dimensional model of emotions (arousal, valence and dominance). The game engine would also provide functions for
modeling affective dynamics, and enable the game designer to modify these. Analogous modeling primitives would be provided for modeling emotion effects on internal processes, as well as on the visible manifestations of emotions by the NPCs.

Summary and Recommendations

This chapter discussed a number of concepts, methods, techniques and tools, relevant for the development of affective serious games for education, training and therapy. The major design tasks are summarized below, along with some alternative design choices. The summary is organized in terms of the key functionalities that affect-sensitive and affect-centered games should provide, to be effective in training, education and therapy. The section concludes with some recommendations for researchers, practitioners and policy-makers.

Summary

To implement recognition of player emotion, the designer must identify the following:

- Player emotions that must be recognized by the game.
- Distinct, idiosyncratic signatures of these emotions in the player, across the available modalities and channels (e.g., facial expressions, autonomic nervous system signals, gameplay behavior).
- Most appropriate non-intrusive sensors, to detect the necessary signals, for a given game context and platform (e.g., desktop, stationary platform vs. mobile device platform).

To implement affective models of players, the designer must identify the following:

- Key elements and structure of the affective player profile (player affective and mixed states, their triggers, and associated behavioral characteristics; relevant personality traits).
- Most appropriate learning algorithms, and the gameplay and player features to use as inputs.
- Appropriate adaptation strategies, to ensure engagement and achieve game objectives.
- Best means to induce desired emotions within the game, via game characters’ affective behavior, narrative and plot structure, music, and gameplay.

To model emotion generation and emotion effects in non-playing characters, the following must be identified:

- Non-playing character emotions that should be modeled, to ensure player engagement and achieve game objectives.
- Specific features of gameplay and non-playing characters to use as input for the emotion generation algorithm.
• Modeling resolution requirements for the necessary degree of affective realism and character believability, for a given game type and platform context.
• Selection of the appropriate model depth (black-box vs. process models); that is, the need for, and complexity of, the NPC agent architecture.
• Most appropriate theoretical perspective and representational primitives for modeling emotion (discrete, dimensional, componential).
• Most appropriate approach to emotion generation (e.g., cognitive appraisal alone vs. multimodal approaches), and the best algorithm for the given choice.
• Appropriate level of accuracy of affective dynamics to achieve desired character realism.
• Specific internal effects, if any, of emotion on cognition that must be modeled to achieve the desired character believability; that is, specific affective biases on attention, perception, decision-making in non-playing characters.

To model expression of emotion in game characters, the following must be identified:

• Degree of visual realism necessary to achieve the desired believability, for the given game objectives and platforms.
• Expressive features of non-playing characters, and their behavioral repertoire, available to depict different emotions, as a function of character appearance, game type, game objectives and platform.
• Distinct multi-modal signatures for the selected emotions, in terms of the expressive features available (depends on game type, degree of realism, platform).
• Most appropriate semantic primitives and markup language for the selected expressive modalities and channels, which can support the necessary cross-modal synchronization.

Recommendations

Successful implementation of the functionalities listed above has the potential to greatly advance the effectiveness of serious games. This will require advances in research and practice, as well as a commitment from policy makers and funding agencies. Some of the key challenges and recommendations are listed below.

Research

Tremendous progress has been made in both gaming and affective computing, that is directly relevant for the development of affect-sensitive and affect-centered serious games. However, many challenges remain, including the following:
• Improved understanding of the roles of emotion in serious gaming, to support design decisions about which emotions should be integrated, when, and in what manner.
• Improved understanding of affective dynamics to enable modeling of believable non-playing
characters.

- Identification of the most useful player traits, for different gaming contexts, to develop useful affective user models; high-level traits such as the Five Factor model (e.g., extraversion, neuroticism, etc.) may not be the most productive for all serious gaming contexts.
- Identification of new mental states (affective and mixed affective-cognitive), which may be gameplay- and player-specific, to help improve gameplay adaptation and game effectiveness. (See, for example, Picard’s discussion of this issue in the context of emotion recognition (Picard, 2000).)
- Development of systematic guidelines for affect-focused game design, for a variety of serious game types, to develop the functionalities outlined above.
- Development of standards and sharable modules to facilitate rapid prototyping, sharing, and evaluation of games and game components.
- Development of tools with embedded semantic primitives at the appropriate level of abstraction, to support principled development of the functionalities outlined above (e.g., the affective game engine (Hudlicka, 2009)).
- Addressing of any ethical issues that may arise as games become more effective in recognizing player emotions, and inducing emotions in players.

**Practice**

All of the research challenges above have direct implications for the development of fielded games. The development of standards, sharable modules, and high-level tools is particularly critical. In addition, the following will be necessary to

- Adherence to theoretically and empirically valid approaches to recognition, modeling and expression of emotion.
- Commitment to affect-focused design, where affective considerations are integrated into the design process, throughout the different stages of development and evaluation.
- Development of, and adherence to, systematic design guidelines to support affect-focused design.
- Development and use of affective envelopes and affective player profiles to guide game development and evaluation.
- Attention to any ethical issues that may arise, and development of appropriate ethical guidelines for the use of affect-centered games.
Policy Makers

The ambitious research challenges and goals outlined above will require a commitment on the part of policy-makers and funding agencies, as well as the management in game companies. All of the challenges listed in the bullets above would benefit from dedicated, long-term research programs. Areas that are particularly critical for advancing the state-of-the-art in serious affective games include support for the following.

- Research efforts to develop standards and sharable repositories of content and components.
- Research in affective computing within gaming, since games represent a distinct context and different requirements for emotion recognition, modeling and expression.
- Development of systematic design guidelines and developments tools.
- Cross-disciplinary workshops and collaborations.
- Development of educational programs and curricula to train researchers and developers of affective serious games in education, training and therapy.

Conclusions

The aim of this chapter was to discuss how the emerging discipline of affective computing contributes to affect-focused game design of serious games for education, training and therapy. The primary focus was on affect-centered games, whose objective is to train affective or social skills, or to provide therapy. In each case, such games need to induce particular affective states in the player and maintain appropriate level of engagement. These games therefore require more affectively-realistic and believable characters, as well as detailed affective models of the players.

Several concepts were introduced that would facilitate the design and evaluation of such games. These included the notion of affect-focused game design, where the actual or desired player emotion during gameplay plays a central role in the game design process, as well as affective player profile, affective gameplay profile and the ideal affective envelope for the player. Each of these structures represents the actual or desired affective states of the player during a gameplay, and serves as a basis for an affective model of the player, and as a design specification of the types of emotions the gameplay should induce in the player.

The chapter provided information about existing data and theories from the affective sciences. These inform decisions about approaches to emotion sensing and recognition,
generation of affective behavior in game characters, and computational affective modeling in affective gaming. A brief overview of the emerging discipline of affective gaming was also provided. This was followed by a more in-depth discussion of the requirements and approaches to modeling emotion in non-playing characters. The chapter discussed the notion of an affective game engine: a high-level game development tool that would provide the necessary modeling and representational primitives to support the design and development of affect-sensitive and affect-centered games. The chapter concluded with a summary of key design issues, and recommendations for researchers, practitioners and policy-makers, to help advance the state-of-the-art in serious affective gaming.

Affective gaming is emerging as a distinct subdiscipline. Its aim is to develop games that are more directly focused on the player’s emotions, and capable of affect-based adaptations to the player’s changing affective state, and affective needs. (More information about the emerging discipline of affective gaming can be found at: www.affectivegaming.org.) Today, the term ‘affective gaming’ generally means adapting to the player’s emotions, to minimize frustration and ensure a challenging and enjoyable experience. The methods developed in affective computing provide many of the tools necessary to advance affective gaming to the next stage: where a variety of complex emotions can be induced in the player, for entertainment, but especially for training and therapeutic purposes.

Methods and techniques from affective computing directly support all three of the phases comprising affective gaming, as suggested by Gilleade and colleagues: “Assist Me, Challenge Me, Emote Me” (Gilleade, Dix et al., 2005). Tools that would directly provide these techniques and structures, such as the affective game engine proposed above, would serve as a foundation for systematic affect-focused game design, and would support the efficient development of affect-centered games for education, training and psychotherapy.

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**Key Terms:**

affective gaming, affective computing, affect-centered games, emotion modeling, affective game engine, affective player profile, affect-focused game design