

AFFECTIVE COMPUTING FOR GAME DESIGN

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ABSTRACT

Affective gaming has received much attention lately, as the gaming community recognizes the importance of emotion in the development of engaging games. Affect plays a key role in the user experience, both in entertainment and in 'serious' games. 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. A significant effort is also being devoted to generating 'affective behaviors' in the game characters, and in player avatars, to enhance their realism and believability. Less emphasis is placed on modeling emotions, both their generation and their effects, in the game characters, and in user models representing the players. This paper discusses how the emerging discipline of affective computing contributes to each of these three elements of affective game design, with emphasis on the importance of affective modeling. The paper provides a summary of a conference tutorial whose aim is to enable game designers to make informed choices about where to incorporate emotion in games, and provide information about existing data and theories from the affective sciences, and relevant methods and techniques from affective computing, to support affect-focused game design.

1.0 INTRODUCTION

Affective gaming has received much attention lately, as the gaming community recognizes the importance of emotion in the development of more engaging games (Becker et al. 2005; Gilleade et al. 2005; Sykes, 2004). Emotion plays a key role in the user experience, both in entertainment, and in 'serious' games developed for education, training, assessment, therapy or rehabilitation. 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; e.g., minimizing frustration, ensuring appropriate challenge (Gilleade and Dix 2004; Sykes and Brown 2003). A significant effort is also being devoted to generating 'affective behaviors' in the game characters, to enhance their realism and believability. Less emphasis is placed on modeling

emotions, both their generation and their effects, in the game characters themselves, and in user models representing the players.

This paper discusses each of these elements of affective gaming, and outlines how the emerging discipline of *affective computing* (Picard 1997) can contribute to integrating emotion in game design. The three core areas of affective computing provide methods and techniques directly relevant to affective game design: *emotion sensing and recognition*; *computational models of emotion*; and *emotion expression by synthetic agents and robots*. This paper emphasizes the importance of affective modeling in particular, both as a basis for more realistic behavior of game characters, but also as a means of developing more realistic and complete models of the players, to enable real-time affect-adaptive gameplay, and to enable the game system to induce a wide range of desired emotions in the players.

The paper summarizes a conference tutorial that introduces these three core areas of affective computing, and highlights their relevance to the development of engaging and effective games. The aim of the tutorial is to provide sufficient information about affective computing methods and techniques, and data and theories from the affective sciences, to enable game designers to make informed choices about where and how to incorporate emotion in games.

2.0 THE ROLES OF EMOTIONS IN GAMING

Emotions are critical in game design. One only has to eavesdrop on a group of kids huddled over a Nintendo DS to hear "AWWW! I GOT KILLED" or "YES!!!! I GOT ANOTHER LIFE" to get a sense of the internal affective drama engendered by gaming. Players become frustrated when the game does not go well, pleased with themselves when they "beat a level", or may turn away in disgust when they encounter a seemingly insoluble problem.

Players' emotions can be triggered by the gameplay events (e.g., finding a treasure), by behavior of a game character, or as a result of interaction with the game (e.g., frustration when the game is too difficult). Emotions can be conveyed to the player by the game character behavior, and by the look-and-feel of the game environment; e.g., contrast the intense, high-arousal graphics of DOOM, the mysterious and foreboding environment of Myst, and the lighthearted Mario games.

The degree of explicit focus on players' emotions in gaming 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 is more ‘fun’ than ‘frustrating’, the players remain engaged and their emotions can be ignored. 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, one that does not require the game system to sense the player’s emotions; e.g., 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 to this, 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, and some aspect of the game is 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 player’s emotion is a key factor, actively manipulated to ensure engagement. This type of dynamic affective adaptation (affective feedback (Bersak et al. 2001)) is the focus of current affective gaming efforts (Becker et al. 2005; Gilleade et al. 2005). Finally, affective games can be applied in therapeutic contexts, where the player’s emotions are 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). Here the recognition of the players’ emotions is essential to support the selection of appropriate gameplay, either affect-adaptive or affect-inducing.

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 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 paper, and the associated conference tutorial, discuss 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.

3.0 WHAT DO WE KNOW ABOUT EMOTIONS?

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 computing and affective human-computer interaction, and to affective game development. The emerging findings inform sensing and recognition of user emotion by machine, computational affective modeling, and the generation of expressive affective behaviors in synthetic agents and robots. This section summarizes some of the key findings relevant for affective game design.

Definitions

When searching for a definition of emotions, it is interesting to note that most definitions involve descriptions of characteristics of affective processing (e.g., fast, undifferentiated processing), or 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., homeostasis, goal management, coordination of multiple systems necessary for action, fast selection of appropriate adaptive behaviors). The fact that emotions are so often defined in terms of their roles, rather than their essential nature, underscores our lack of understanding of these complex phenomena. Nevertheless, emotion researchers do agree on a high-level definition of emotions, 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 neural functioning reflected across multiple modalities (e.g., cognitive, physiological, behavioral) and coordinating multiple cognitive and behavioral subsystems 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. In biological agents, emotions are manifested across four interacting modalities. 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., changes in the neuroendocrine systems and their 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, discussed below. Finally, there is the *experiential / subjective modality*: the conscious, and inherently idiosyncratic, experience of emotions within the individual.

Understanding the ‘signatures’ of specific emotions across these multiple modalities provides guidance for sensing and recognition of player emotions, and for the generation of affective behavior in agents, as will be discussed below in section 4.

Affective Factors

The term ‘emotion’ can often be used rather loosely, to denote a wide variety of affective factors, each with different implications for sensing and recognition, modeling and expression. *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*, 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). The set of *basic emotions* typically includes 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. affective emotionality).

Emotion Generation and Emotion Effects

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, termed the ‘cognitive appraisal’ theories of emotion (Roseman and Smith 2001). A key component of most appraisal theories is a set of domain-independent appraisal dimensions which capture aspects of the stimuli and the assessed situation the agent is facing, such as novelty, urgency, likelihood, goal relevance and goal congruence, responsible agent and the agent’s ability to cope (Ellsworth and Scherer 2003; Smith and Kirby 2000). This approach to appraisal, also termed componential model of emotions, provides an elegant conceptualization of the generation process and facilitates modeling. If the values of the dimensions can be determined, the resulting vector of ‘appraisal dimensions’ can readily be mapped onto the emotion space defined by these dimensions, which in turn provides a highly-differentiated set of possible emotions.

Less understood are the processes that mediate the *effects of the triggered emotions*. The manifestations of specific emotions in behavior 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. Some effects on cognition are also known; e.g., fear reduces attentional capacity and biases attention toward threat detection (Isen 1993; Mineka et al. 2003)). However, the mechanisms mediating these observed effects have not yet been identified. The interactions among multiple modalities make this a particularly challenging problem.

Three broad categories of theories postulate specific mechanisms mediating emotion effects. *Spreading activation models*, such as Bower’s “network theory of affect” (Bower 1992; Derryberry 1988), were developed to explain the phenomenon of mood-congruent recall. These conceptual models suggests that emotions can be represented as nodes in a network that contains both emotions and cognitive schemas. When an emotion is activated, it co-activates (via spreading activation) schemas with similar affective tone. The *componential theory* suggests that the domain-independent appraisal dimensions that mediate emotion generation map directly onto specific elements of affective expressions, such as the facial musculature; e.g., novelty correlates with eyebrow raising, pleasantness with raising of lip corners and eye lids (Scherer and Ellgring 2007), and possibly even onto emotion effects on cognition (Lerner and Tiedens, 2006). The *parameter-based models*, proposed independently by a number of researchers (e.g., Hudlicka 1998; Matthews and Harley 1993; Ortony et al. 2005; Ritter and Avramides, 2000), suggest that affective factors act as parameters inducing patterns of variations in cognitive processes. The parameter-based models appear consistent with recent neuroscience theories, suggesting that emotion effects on cognition are implemented in the brain via global effects of neuromodulatory transmitters that act systemically on multiple brain structures (Fellous 2004).

4.0 EMOTION SENSING, RECOGNITION AND EXPRESSION: EMOTION SIGNATURES ACROSS MULTIPLE MODALITIES AND TIME

The *multi-modal nature of emotions*, and their evolution over time, both facilitate and constrain recognition of emotions in players, and generation of expressive affective behavior in game characters. Many emotions have characteristic multi-feature, multi-modal ‘signatures’ that serve as basis for both recognition and expression; e.g., fear is characterized by raising of the eyebrows (facial expression), fast tempo and higher pitch (speech), threat bias attention and perception (cognition), a range of physiological responses mobilizing the energy required for fast reactions, and of course characteristic behavior (flee vs. freeze). Identifying such unique emotion signatures is a key challenge in emotion recognition by machines. Once identified, the constituent features guide the selection of appropriate (non-intrusive) sensors, and the algorithms required for the associated signal processing to map the raw data onto a recognized emotion. For example, frustration can be identified with a high degree of accuracy (~80%) by combining facial expression analysis, posture, skin conductance and mouse pressure data (Kapoor et al. 2008).

The multiple modalities thus facilitate recognition by providing multiple “channels” of information, and options for the selection of the best channel for a particular application. Affective gaming presents a unique set of constraints on recognition, by requiring non-intrusive sensors and precluding methods that require fixed player positions. For example, sensors that detect arousal, a key component of emotions, such as finger-tip caps to detect galvanic skin response or heart-rate monitors, are not optimal for gaming, nor are facial recognition systems that require the player to remain in a fixed position. Instead, emotion recognition in gaming emphasizes sensors that can be readily incorporated into existing game controls; e.g., gamepad pressure to detect arousal (Sykes and Brown 2003). Products are also emerging that offer helmet-embedded sensors combining multiple channels (EEG, facial electromyogram, blink rate, heart rate, head motion and skin temperature) to recognize game-relevant player states, such as engagement vs. boredom (e.g., <http://www.emotiv.com/>, <http://emsense.com/>). The advent of movement-oriented controls, such as those in the Wii, promises to provide a rich set of affective sensors based on movement quality and haptics.

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 expression however, 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. However, for a given game character or situation, all of these channels may not be required; e.g., “cartoonish” characters may be able to express many basic emotions (joy, anger, sadness) with minimal changes in expression, movement and behavior. However, as games mature and proliferate into more ‘serious’ applications, these coordination requirements will become more stringent.

The *temporal dimension of emotions* facilitates recognition and presents challenges for expression. Temporal affective data increase recognition accuracy. In some channels (e.g., facial expressions), recognition is much higher for video clips than for still photographs. In many modalities, the temporal dimension is an essential component (e.g., speech, movement, behavior monitoring, but also physiological data).

In affective expression, the temporal dimension presents a challenge by requiring realistic evolution of the affective state, and transitions among states. This requires data regarding how the affective dynamics are reflected in changes in facial expressions, speech and movement, as the emotion intensity ramps up and decays. Particularly challenging are the depictions of mixed affective states (e.g., sadness and joy, fear and anger) and transitions among states, which may need to be gradual for some situations but dramatic for others. For some modalities, these dynamics are well-documented (e.g., the *facial action units* vocabulary of facial expressions (Ekman and Friesen 1978) that define the onset and offset patterns (Cohn et al. 2005)), but in general, these dynamics are determined empirically and require significant tuning.

The sensing and recognition of emotions, and the expression of their myriad of manifestations in game characters, thus require fundamental knowledge of emotions and their unique multi-modal signatures, selection and integration of sensors satisfying the desired constraints (e.g., degree of intrusiveness allowed, cost and ease of use, data quality, post-processing requirements of the raw data), selection or development of algorithms for data enhancement and filtering, and for pattern recognition and classification. Given the idiosyncratic nature of affective expression, the use of player baseline data is essential, and typically user-specific training of the recognition algorithms is required to achieve the desired level of accuracy.

A key element in this process is the identification of the semantic primitives for each sensed channel, and a development of an associated vocabulary of primitives, whose distinct configurations can then characterize the different emotions (Hudlicka, 2005). Examples of such semantic primitives are the facial action units comprising the Facial Action Coding System developed by Ekman and Friesen (1978), the ‘basic posture units’ identified by Mota and Picard (2004) and used to identify boredom and engagement during training, and patterns of pitch and tonal variations in speech used to identify basic emotions (Petruhin 2000).

The conference tutorial discusses specific emotion signatures, and associated methods and approaches for recognition and expression, in more detail.

5.0 COMPUTATIONAL AFFECTIVE MODELING AND AFFECTIVE USER MODELS

The past 15 years have witnessed a rapid growth in computational models of emotion and affective architectures. Researchers in cognitive science, artificial intelligence and human computer interaction (HCI) are developing models of emotion for theoretical research regarding the nature of emotion, as well as a range of applied purposes: to create more believable and effective synthetic characters and robots, and to enhance HCI (Becker et al. 2005; Breazeal 2005; Kapoor et al. 2008). Computational models of emotion are relevant for game development from two distinct perspectives. *First*, affective computational models enable the game characters to dynamically generate appropriate affective behavior in real time, in response to evolving situations within the game, and to player behavior. Such adaptive character behavior is more believable than ‘scripted’ behavior, and the resulting realism contributes to an increased sense of engagement. These models also enable the characters to consistently and realistically portray specific emotions when the game objective is to induce a particular emotion in the player, as is the case in psychotherapeutic games. *Second*, computational affective modeling methods can also be used to create affective models of the players; that is, user models that explicitly include information about the player’s affective makeup. This includes information such as what emotional states a player is likely to experience, information about the behavioral indicators associated with different emotions that can aid in their recognition by the game system, and what game situations are likely to induce a particular emotion. Both of these uses of computational affective modeling are briefly described below, and elaborated in the conference tutorial.

5.1 Computational Affective Modeling

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, very simple models are adequate, where 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).

Such simple models are termed ‘black-box’ models, because 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, resulting in more involved plots and narratives, and associated increase in the sophistication of the game characters and richness of player interactions, the need for more sophisticated affective modeling arises. This may in some cases require ‘process-

models’, where explicit representations of some of the affective mechanisms are modeled, allowing a greater degree of generality.

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 across the multiple modalities (Hudlicka 2008a; 2008b). Each of these broad categories of processes are then further divided into their underlying primitive computational tasks. For emotion generation, these include defining the stimulus-to-emotion mapping; specifying the nature of the emotion dynamics, that is, the functions defining the emotion intensity calculation, as well as the ramp-up and decay of the emotion intensity over time; 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 tasks include defining the emotion-to-behavior and emotion-to-cognitive process mappings; determining the magnitude of the associated effects on each affected process, as well as the dynamics of these effects; and the 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.

Modeling Emotion Generation

As stated above, 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; Frijda 1986; Lazarus 1984; Mandler 1984; Roseman and Smith 2001; Scherer et al. 2001; Smith and Kirby, 2001). Most existing computational models of appraisal are based on either the OCC model (Ortony et al. 1988), or the explicit appraisal dimension theories developed by (Scherer et al. 2001; Smith and Kirby 2000), 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., Andre et al. 2000; Bates et al. 1992; Broekens and DeGroot 2006; 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 extract the appraisal dimension values. This may 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.

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 generally follows a simple monotonically increasing (ramp-up) and decreasing (decay) function over time. 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 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, in some cases using customized, domain-dependent weightings (e.g., some emotion is emphasized in a particular situation over another emotion, possibly as a function of the character's personality). Each of these approaches has limitations, which are discussed in more detail in the tutorial. 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 and the computational solutions are 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 less visible, but no less dramatic, effects on attention, perception and cognition. Majority of existing emotion models of emotion effects focus on the former. While technically challenging, the behavioral effects are easier from a modeling perspective, 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). While the tutorial will address both the behavioral effects, and the effects on cognition, due to space limitations the discussion below will focus on cognitive effects only.

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 likely emerge, particularly so in therapeutic games, where the assessment and triggering of specific emotions is the focus; e.g., games designed to support cognitive-behavioral therapies, and the associated cognitive restructuring, will require explicit modeling of emotion effects on cognition to implement the treatment protocols.

While data are available regarding some of the emotion effects on cognition (see section 3), the mechanisms of these processes have not been identified and this presents challenges for the modeler, frequently resulting in black-box models rather than mechanism-based process models. Nevertheless, several recent efforts focus on the process-models of emotion effects on cognition, most often in terms of parametric-modification of cognitive processes (e.g., Hudlicka 2003; 2007; Ritter et al. 2007; Sehaba 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 (Busemeyer et al., 2007; Lisetti & Gmytrasiewicz, 2002).

Modeling emotion effect magnitude and dynamics 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.

5.2 Affective User Modeling

Affective user models are representational structures that store information about the affective makeup of the player: which stimuli trigger which emotions, what behaviors are associated with different emotions, etc. Such models serve a critical role in affect-adaptive gaming, supporting both emotion recognition, and the generation of an appropriate affect-adaptive strategy by the game system. Since affective behavior can be highly idiosyncratic, affective models typically involve a learning component, so that the player's behavior can be tracked over time and the important affective patterns extracted from monitoring of the player's state and game interactions. For example, Player A may express his frustration by more forceful manipulation of the game controls, while Player B may express frustration through increasing delays between game inputs.

The knowledge and inferencing required to support these functionalities can take a number of forms. A useful representation is an augmented state transition diagram or a hidden Markov model (Picard, 1997) that explicitly indicates the known states of the user (e.g., happy, sad, frustrated, bored, excited), the situations and events that trigger these transitions (e.g., in gaming context, loss or gain of points or game resources; appearance or disappearance of a particular game character, etc.), and the player's behavior (or other monitored characteristic) that indicate each emotion. The tutorial discusses the structures, development, and use of affective user models in more detail.

6.0 SUMMARY AND CONCLUSIONS

This paper summarized key ideas from an associated GAMEON 08 tutorial on "Affective Computing and Game Design". The aim of the tutorial is to discuss how the emerging discipline of affective computing contributes to affect-focused game design. The paper also provided information about existing data and theories from the affective sciences that inform decisions about approaches to emotion sensing and recognition, generation of affective behavior in game characters, and computational affective modeling in affective gaming.

Gaming researchers emphasize the importance of affective game adaptations to the player's emotions, to ensure engagement and enhance effectiveness of serious games. 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 take affective gaming to the next stage: where a variety of complex emotions can be induced in the player, for both entertainment and training and therapeutic purposes. Affective computing thus directly supports all three of the phases comprising affective gaming, as suggested by Gilleade and colleagues: "Assist Me, Challenge Me, Emote Me" (Gilleade et al. 2005), and the methods and techniques developed in affective computing can serve as a foundation for affect-focused game design.

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