Emotion in Games

Georgios N. Yannakakis and Ana Paiva

Abstract

Emotion has been investigated from various perspectives and across several domains within human computer interaction (HCI) including intelligent tutoring systems, interactive web applications, social media and human-robot interaction. One of the most promising and, nevertheless, challenging applications of affective computing (AC) research is within computer games. This chapter focuses on the study of emotion in the computer games domain, reviews seminal work at the crossroads of game technology, game design and affective computing and details the key phases for efficient affect-based interaction in games.

Keywords

Computer games, affective loop, game content, non-player characters, emotion elicitation, emotion modelling, emotion expression

1. Introduction

People choose to play games as a “voluntary attempt to overcome unnecessary obstacles” (Suits, 2005) as play is amongst the main motivators for learning, mental and physical development, and an essential element of evolution (Deci & Ryan, 2000). Arguably, players seek games for enjoyment and for emotional experiences and pursue in-game challenges that – when achieved – do not necessarily result in immediate, tangible, rewards. What is fascinating is that players willingly engage in an experience that is likely to even involve negative emotions such as frustration and fear (Salen & Zimmerman, 2003). So, while games can be utilised as an arena for eliciting, evaluating, expressing and even synthesising emotions, we argue that one of the primary aims of the study of emotion in games is the understanding of players’ emotions and its link with their experience. Indeed, by the nature of what constitutes a game, one cannot dissociate games from emotions. Emotions are not only the trigger for the positive game experiences, but also one of the main targets for game design. For this purpose, this chapter focuses on emotions that can be detected, modelled from, and expressed in games with human players.

Computer games are dynamic media which embed rich forms of user interactivity. Collectively, such HCI attributes allow for high levels of player incorporation (Calleja, 2011) and yield dynamic and complex emotion manifestations. The potential that games have to influence players is mainly due to their ability of placing the player in a continuous mode of interaction (loop) with the game which develops complex cognitive, affective and behavioural responses. Undoubtedly, the study of emotion in games not only advances our knowledge about human emotions but also contributes to the design of better human-computer interaction. Moreover, affect-based game interaction can drive players in particular emotional patterns which, in turn, can enhance game-based training and educational activities (McQuiggan, Robison, & Lester, 2010), (McQuiggan & Lester, 2009), (Yannakakis G. N., et al., 2010). Arguably, as we will see in this chapter, games offer the best and most meaningful domain of affective interaction for the realisation of the *affective loop* which defines a system that is able to successfully elicit, detect and respond to the emotions of its user (Sundstrom, 2005).

Every game features a *user* (i.e. *player*) – or a number of users – which control an avatar or a group of miniature entities in a virtual/simulated environment (Calleja, 2011). The interaction between the player and the game context (i.e. the game state containing all pieces of game content) is of key importance for affective computing (AC) research and modern game development as it breeds emotional stimuli and yields emotional manifestations to the player – those manifestations, however, cannot trivially be captured by standard methods in AC research. Given the particularities of emotion research in games we both discuss what games can offer to emotion research but also what emotion research can bring to game design and game technology research.

1.1 What Games Can Do for Emotion Research

As mentioned earlier in this section, games can offer contextual building blocks (i.e. game content) that can elicit a broad spectrum of emotional responses and emotional patterns. Games – as a medium – have unique properties that make this possible as they incorporate rich forms of interaction with the player within a virtual world, provide a direct placement of a player onto an avatar and a player detachment from reality, and finally allow for a direct control of the context presented to the player. For these unique features, games can be used (and have been used quite extensively) by emotion researchers as handy and off-the-shelf emotion elicitors.

More importantly, games can offer the most meaningful realization of the *affective loop* (Sundstrom, 2005). As games are by definition both *entertaining* (whether used for pure satisfaction, training or education) and *interactive* activities that are played within *fantasy* worlds, any limitations of affective interaction (such as justifiability of affective-based game decisions) are absorbed. Games are designed to offer affective experiences which are influenced by player feedback and players are willing to go through e.g. frustrating, anxious, and fearful episodes of play to experience involvement and powerful emotional gaming. To that end, a user under gaming conditions – more than any other form of HCI – is generally open to affective-based alterations of the interaction and influences of his/her emotional state.

1.2 What Can Emotion Research Do for Games?

The use of AC research and development in games is beneficial for the design of better games for various reasons. First, emotions can drive the design process of most game genres. Game designers usually explore and test a palette of mechanics and game dynamics that yield emotional states and emotional state sequences they desire to put the player through. Emotional states such as engagement, fear and stress, frustration, and anticipation but also cognitive states such as challenge define critical aspects of the design of player experience, which is dependent on the genre, the narrative and the objectives of the game. Second, the holy grail of game design, that is *player experience*, can be improved and tailored to each player but also augmented via richer and more affective-based interaction. As we will see in the following section and in the discussion of this chapter, emotion-driven game adaptation primarily targets the personalisation of the playing experience. Third, as a direct consequence of better and faster design, the whole game development process is boosted and improved. Fourth, games that incorporate rich emotion-based interaction which is further tailored to the needs of the player can enhance learning in training or educational (game-based learning) settings as indicated by numerous studies in the literature (McQuiggan & Lester, 2009), (McQuiggan, Robison, & Lester, 2010), (Yannakakis G. N., et al., 2010).

Research on emotion in games is nowadays becoming increasingly important in research and development departments of top-class (i.e. AAA) and indie game developers (Yannakakis G. N., 2012). More specifically, there exist several commercial-standard games that incorporate emotion as a core (or peripheral) part of gameplay including the arousal-driven appearance of non-player characters (NPCs) in *Left 4 Dead* 2 (Valve Corporation, 2009), the fearful combat skills of the opponent NPCs in *F.E.A.R.* (Monolith, 2005), the avatars' emotion expression in the *Sims* series (Maxis, 2000) and *Black and White* (Lionhead Studios, 2001), the emotional play-through for characters in *Psychonauts* (Double Fine Productions, 2005), the emotional responses of game characters in *Prom Week* (McCoy, et al., 2010) and *Façade* (Mateas & Stern, 2003), the emotion-driven narrative building system in *Storybricks* (Namaste Entertainment, 2012), the personality-based adaptation in *Silent Hill: Shattered Memories* (Konami, 2010), the affect-based cinematographic representation of multiple cameras in *Heavy Rain* (Quantic Dream, 2010), the aesthetically pleasing locations of *World of Warcraft* (Blizzard Entertainment, 2004) and affect-centred game narratives such as the one of *Final Fantasy VII* (Square Product, 1997).

Ultimately, all above-mentioned intelligible benefits from the coupling of games and emotion research can be revealed as long as phases of the affective loop (or the affective loop as whole) are successfully realised within a game.

1.3 The Affective Loop in Games

Within games, emotions are elicited via stimuli offered during the interaction. Emotions can then be detected and modelled, assessing the responses of the player to the corresponding game stimuli. Such detection can then affect the game responses that may involve emotions expressed in several ways via game-adjustable elements such as game content and non-player characters; and finally, controllable game elements can be adapted dynamically to cater for the current emotional state of the player and the specific game context. The affective loop (Sundstrom, 2005) when applied to games can be viewed as comprised of three sequential key phases organised in a closed loop: (see Figure 1).

1) the player expresses her emotions through the interaction with a game;
2) the game then detects the emotional reactions of the player, and interprets those reactions according to the context of the game;

3) based on that interpretation, the game makes adjustments that can be achieved via emotional modelling and expression of NPCs or via affect-driven content generation adapting the game to the player. This in turn affects the player (both her mind and body) making her respond through game actions and emotional reactions (step 1 again).

The remaining three sections of this chapter discuss the three affective loop phases in detail under the games domain. The chapter ends with a discussion about the open questions and the future of research on emotion in games.

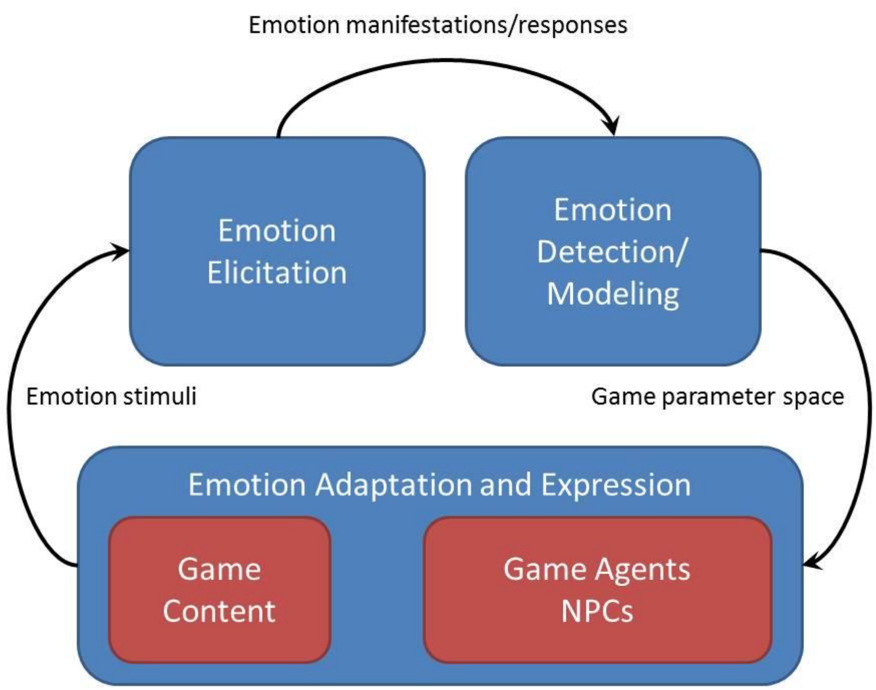

Figure 1: The realisation of the affective loop in games

2. Games as Emotion Elicitors

Emotion elicitation in games can be achieved primarily through interaction with particular game elements (such as game characters and the rest of the game content). While social interaction (shared involvement (Calleja, 2011)) may have a clear impact on a player's emotional state it cannot be directly controlled via an affective loop mechanism and thereby is not included in the list of emotional stimuli considered in this chapter. On that basis, we may define *two* key clusters of possible emotion elicitors in games:

1) **Game content:** beyond any narrative or player-agent interaction there is game content that can influence the emotional state of the player. Game content refers to the game environment (i.e. spatial involvement according to (Calleja, 2011)) but also refers to fundamental game design building blocks such as game mechanics (i.e. ludic involvement according to (Calleja, 2011)), story plot points and reward systems. More specifically, beyond the game environment itself – such as a game level/map (Hullett & Whitehead, 2010), (Togelius, et al., 2010) – game content includes audiovisual settings such as lighting (Seif, Vasilakos, C., & Zupko, 2009), saturation, and music (Eladhari, Nieuwdorp, & Fridenfalk, The soundtrack of your mind: mind music-adaptive audio for game characters , 2006) and sound effects (Plans & Morelli, 2012) but also virtual camera profiles and effects (Picardi, Burelli, & Yannakakis, 2011), (Yannakakis, Martinez, & Jhala, 2010) and game rules (Togelius & Schmidhuber, 2008). All above-mentioned types of content can be adjusted to affect the playing experience and influence player emotions.

   The environment is linked to stories and narratives as a form of their representation and it is also linked to NPCs (if existent in the game) as it forms their context, living habitats and surroundings. In a broader sense, both agents and narratives can be viewed as game content that can be parameterised and altered (Yannakakis & Togelius, 2011). Stories play an essential part in creating the ambience, style, climax and feelings of a game; whether games can tell stories (Juul, 2001) or games are instead a form of narrative (Aarseth, 2004) is still, however, an open research question in game studies. Players seek the moment-to-moment experiences they build in a game and the climax and relief moments created by pre-scripted story elements. Some games such as *World of Warcraft* (Blizzard Entertainment, 2004) take advantage of the story components and in particular cut scenes to raise the climax and lead the player to particular emotional states. Other systems, in particular in the area of interactive storytelling, use the story as an evolving and adaptive mechanism that in itself varies according to the actions of the players, and adjusts the story to different players and actions, offering variant emotional experiences (see e.g. the work of Roberts et al. (2009) among others). Further, by breaking the game narrative into subareas of game content (and perhaps according to the different plot phases) we can find core game content elements such as the game's plotline (Riedl, 2012), (Giannatos, Nelson, Cheong, & Yannakakis, 2012), but also the ways this story/plot is represented in the game environment.

In summary, all game content surrounding NPCs (whether those are existent in the game or not) including game mechanics, rules, story nodes and reward systems may have an effect on the experience of the player (Yannakakis & Togelius, 2011).

2) **Game non-player characters:** Complex, social and emotional non-player characters (NPCs) can be used as triggers of desired emotions for the player. The main goal of these characters is to be believable in a manner that players establish relations with them, thus leading to particular emotional reactions when something good or bad happens in the game. To achieve that, agents may embed computational models of cognition, behaviour and emotion and attempt to react in a believable and human-like fashion to human player actions. Typical agent architectures rely on particular theories of emotion, such as the OCC theory (Ortony, Clore, & Collins, 1988) or Lazarus theory (Lazarus, Emotion and Adaptation, 1994) as the basis for their emotional processing and simulation. One of such architectures, the FAtiMA architecture (Dias & Paiva, 2005) is based on OCC and extends the typical the belief-desire-intention (BDI) (Georgeff, Pell, Pollack, Tambe, & Wooldridge, 1999) model with emotional processing capabilities. A non-inclusive list of games that make use of emotion-driven NPCs includes the kittens in *Kinectimals* (MS Game Studios, 2010), the complex social agents in *FearNot!* (Paiva, et al., 2004), the emotional opponents in the iterative prisoner's dilemma (De Melo, Zheng, & Gratch, 2009) and the agents of *Prom Week* (McCoy, et al., 2010).

3. Emotion Detection and Modelling in Games

The detection and modelling of emotion in games is, primarily, the study and use of artificial and computational intelligence (AI and CI) techniques for the construction of computational models of the emotions of players. Emotion detection and emotion modelling bring an AI umbrella to the multidisciplinary intersection of the fields of user (player) modelling, affective computing, experimental psychology and human-computer interaction. Emotion detection in games is an area that has provided the most research studies thus far, leaving, however, large unexplored spaces.

One can detect the emotion of either a human player or a non-player game character. While the challenges faced in the latter case are substantial, the issues raised from emotion detection on human players define a far more complex and important problem for the realization of the affective loop in games. By clustering the available approaches for emotion modelling we are faced with either *model-based* or *model-free* approaches (Yannakakis & Togelius, 2011) as well as potential hybrids between them. The space between a completely model-based and a completely model-free approach can be viewed as a continuum along which any emotion modelling approach might be placed. While a completely model-based approach relies solely on a theoretical framework that maps player's responses to affect, a completely model-free approach assumes there is an unknown function between modalities of user input and affect that a machine learner (or a statistical model) may discover, but does not assume anything about the structure of this function. Relative to these extremes, all approaches may be viewed as hybrids between the two ends of the spectrum, containing elements of both approaches.

The rest of this section presents the key elements of both model-based and model-free approaches and discusses the core components of a derived computational model (i.e. model input, model output and common modelling tools).

3.1 Model-Based (top-down) approaches

According to a model-based (Yannakakis & Togelius, 2011) approach a model of emotion is usually built on a theoretical framework or is entirely based on a theory of emotion. Such a top-down approach to emotion detection and modelling refers to emotional models derived from emotion theories (e.g. cognitive appraisal theory (Frijda, 1986)) such as the emotional dimensions of arousal and valence (Feldman, 1995) and Russell's circumplex model of affect (Russell, 1980), in which emotional manifestations are mapped directly to specific emotional states — e.g. the increased heart rate of a player corresponds to high arousal and therefore to player excitement. Within game studies examples include the theoretical model of incorporation (Calleja, 2011) proposed as an approach to capture player immersion in games composed of six types of player involvement: affective, kinaesthetic, spatial, shared, ludic, and narrative. Seminal work in psychology-based approaches to player emotion includes the concepts of *challenge*, *curiosity* and *fantasy* of Malone (1980) which collectively contribute to high entertainment, and the theory of *flow* (Csikszentmihalyi, 1990) incorporated in games (Sweetser & Wyeth, 2005).

Within game design the theory of ‘fun’ by Koster (2005), the notion of the ‘magic circle’ in games (Salen & Zimmerman, 2003) and the four “fun” factor model of Lazzaro (2004) constitute popular views that place players’ emotions at the centre of player’s experience. Model-based approaches can also be inspired by a general theoretical framework of behavioural analysis and/or cognitive modelling such as usability theory (Isbister & Schaffer, 2008), the belief-desire-intention (BDI) model, the cognitive theory by Ortony, Clore, & Collins (1988), Skinner’s model (1938), and Scherer’s theory (1993).

Even though the literature of theories on emotion is rich, one needs to be cautious with the application of such theories to games (and game players) as their majority have not been derived from or tested on ergodic (i.e. interactive) media such as games. Calleja (2011), for instance, reflects on the inappropriateness of the concepts of ‘flow’, ‘fun’ and ‘magic circle’ (among others) for games. Finally, while ad-hoc designed emotion models can be an extremely powerful and expressive way of representing emotions, these models need to be cross-validated empirically, which is a rare practice in AC research.

3.2 Model-free (bottom-up) approaches

Model-free approaches refer to the construction of an unknown mapping (model) between (player) input and an emotional state representation. Player data and annotated affective states are collected and used to derive the model. Classification, regression and preference learning techniques adopted from machine learning or statistical approaches are commonly used for the construction of the computational model. This approach is very common, for instance, for facial expression and head pose recognition since subjects are asked to annotate facial (or head pose) images of users with particular affective states (see (Shaker, Asteriadis, Yannakakis, & Karpouzis, 2011) among others) in a crowdsourcing fashion. A bottom-up approach is also common in studies of psychophysiology in games (see (Tognetti, Garbarino, Bonarini, & Mateucci, 2010), (Yannakakis, Martinez, & Jhala, 2010) among others).

The model-free approach to emotion modelling offers the tremendous advantages of data-driven (and even large-scale crowdsourced) model building but it also limits itself to the quantity and quality of the data gathered.

3.3 The model's input

The model's input can be of three main types: a) anything a human player (or an agent) is doing in a game environment gathered from **gameplay** data (i.e. behavioural data); b) **objective** data collected as bodily responses to game stimuli such as physiology and body movements; and c) the **game context** which comprises of any player-agent interactions but also any type of game content viewed, played through, and/or created. The three input types are detailed in the remaining of this section.

Gameplay (behavioural) input: The main assumption behind the use of behavioural (gameplay-based) player input is that player actions and real-time preferences are linked to player experience as games may affect the player's cognitive processing patterns and cognitive focus. On the same basis, cognitive processes may influence emotions; one may infer the player's emotional state by analysing patterns of the interaction and associating user emotions with context variables (Gratch & Marsella, 2005), (Conati, 2002). Any element derived from the interaction between the player and the game forms the basis for gameplay-based emotion detection and modelling. This includes detailed attributes from the player's behaviour (i.e. *game metrics*) derived from responses to system elements (i.e. non-player characters, game levels or embodied conversational agents). Game metrics are statistical spatio-temporal features of game interaction (Drachen, Thurau, Togelius, Yannakakis, & Bauckhage, 2013). Such data is usually mapped to levels of cognitive states such as attention, challenge and engagement (Conati, 2002), (Shaker, Asteriadis, Yannakakis, & Karpouzis, 2011). In addition, both general measures (such as performance and time spent on a task) and game-specific measures (such as the weapons selected in a shooter game) are relevant.

Objective input: Games can elicit player emotional responses which, in turn, may affect changes in the player's physiology, reflect on the player's facial expression, posture and speech, and alter the player's attention and focus level. Monitoring such bodily alterations may assist in recognizing and synthesising the emotional responses of the player. The *objective* approach to emotion modelling (i.e. the second type of *objective* model input) incorporates access to multiple modalities of player input.

Within objective emotion modelling, a number of real-time recordings of the player may be investigated. There are several studies that explore the interplay between physiology and gameplay by investigating the impact of different gameplay stimuli to dissimilar physiological signals. Such signals are usually obtained through electrocardiography (ECG) (Yannakakis, Martinez, & Jhala, 2010), photoplethysmography (Yannakakis, Martinez, & Jhala, 2010), (Tognetti, Garbarino, Bonarini, & Mateucci, 2010), galvanic skin response (GSR) (Mandryk & Inkpen, 2004), respiration (Tognetti, Garbarino, Bonarini, & Mateucci, 2010), electroencephalography (EEG) (Nijholt, 2009) and electromyography (EMG).

In addition to physiology one may track the player's bodily expressions (motion tracking) at different levels of detail and infer the real-time affective responses from the gameplay stimuli. The core assumption of such input modalities is that particular bodily expressions are linked to basic emotions and cognitive processes. Motion tracking may include body posture (Savva, Scarinzi, & Bianchi-Berthouze, 2012) and head pose (Shaker, Asteriadis, Yannakakis, & Karpouzis, 2011) as well as gaze (Asteriadis, Karpouzis, & Kollias, 2008) and facial expression (Pantic & Caridakis, 2011).

Game context input: in addition to gameplay and objective data, the context of the game is a necessary input for emotion modelling. Game context refers to the real-time parameterised state of the game. Without the game context input, affective player models run into the risk of inferring erroneous affective states for the player. For example, an increase in galvanic skin response (GSR) can be linked to a set of dissimilar high-arousal affective states such as *frustration* and *excitement*; thus, the cause of the GSR increase (e.g. a player's death or level completion) needs to be fused within the GSR signal and embedded in the model.

3.4 The model's output

The model's output is usually a set of particular affective states (i.e. classes), a scalar (or a vector of numbers) that maps to an emotion such as the emotional dimensions of arousal and valence, or a relative strength of an emotion (i.e. rank or preference). The output of the model is provided through an annotation process which can either be driven by first person reports (self-reports) or by reports expressed indirectly by experts or external observers (Yannakakis & Togelius, 2011).

The most direct way to annotate an emotion is to ask the players themselves about their playing experience and build a model based on these annotations. Subjective emotion annotation can be based on either players' free-response during play or on forced data retrieved through questionnaires. Alternatively, experts or external observers may annotate the playing experience in a similar fashion. Third-person emotion annotation entails the identification of particular affective states (given in various types of representation as we will see below) by user experience and game design experts. The annotation is usually based on the triangulation of multiple modalities of player and game input such as the player's head pose, in-game behaviour and game context (Shaker, Asteriadis, Yannakakis, & Karpouzis, 2011).

Annotations (either forced self-reports or third-person) can be classified as *rating* (*scalar*), *class* and *preference*. In *rating*, annotators are asked to answer questionnaire items given in a rating/scaling form (e.g. in (Mandryk & Inkpen, 2004)) – such as the affective aspects of the Game Experience Questionnaire (Poels & IJsselsteijn, 2008) – which labels affective states with a scalar value (or a vector of values). In a *class*-based format subjects are asked to pick an affective state from a particular representation which could vary from a simple boolean question (*was that game level frustrating or not? is this a sad facial expression?*) to an affective state selection from e.g. the Geneva Emotion Wheel (Scherer, What are emotions? And how can they be measured?, 2005). Finally, subjects are able to provide answers in a *preference* format, in which they are asked to compare an affective experience in two or more variants/sessions of the game (e.g. (Yannakakis G. N., Preference Learning for Affective Modeling, 2009) among others) (*was that level more engaging that this level? Which facial expression looks happier?*). A recent comparative study has exposed the limitations of rating approaches over ranking questionnaire schemes (e.g. pairwise preference) which include increased order of play and inconsistency effects (Yannakakis & Hallam, Rating vs. Preference: a comparative study of self-reporting, 2011).

3.5 Modelling Tools

The tools for constructing models of emotion rely on the modelling approach followed: model-based or model-free. For the model-based approach components of the model and any parameters that describe them are constructed in an ad-hoc manner and, sometimes, tested for validity on a trial and error basis. No machine learning or sophisticated computational tools are required for model-based approaches even though one could envisage the optimization of the parameter space to yield more accurate models; that, however, would require empirical studies which brings the approach closer to a model-free perspective.

Model-free tools for creating models of emotion, on the other hand, are dependent on the type of model output available. If data recorded includes either a *scalar* representation of affect (e.g. via ratings) or *classes* of annotated labels of affective states, any of a large number of machine learning (regression and classification) algorithms can be used to build affective models. Available methods include artificial neural networks, Bayesian networks, decision trees, support vector machines and standard linear regression. Alternatively, if affect is annotated in a *preference* (i.e. ranked) format, standard supervised learning techniques are inapplicable, as the problem becomes one of preference learning (Yannakakis G. N., 2009). Neuro-evolutionary preference learning (Yannakakis G. N., 2009) and rank-based support vector machines (Joachims, 2002) but also simpler methods such as linear discriminant analysis (Tognetti, Garbarino, Bonarini, & Mateucci, 2010) are some of the available approaches for learning preferences. Finally, unsupervised methods such as self-organizing maps, neural gas and sequence mining (Martinez & Yannakakis, 2011) can be used to identify clusters within the model's input space and profile players accordingly. Empirical studies suggest that the model accuracy is improved when such clusters are fed as complementary input to the model (Martinez, Hullett, & Yannakakis, 2010).

4. Emotional Adaptation and Expression in Games

Emotions are fundamental for players to deeply engage with games. Players' responses in a game are affected by their emotional states. If, in turn, these states could be used to affect the way the game responds, the player-game interaction could be augmented and enriched by magnitudes, realizing *affective loop*-enabled games. Games may evolve and adapt to the player in many different ways and convey emotions through a variety of techniques and effects. In this section we will discuss emotion adaptation and emotion expression, placing it in the context of the affective loop discussed earlier. The adaptation module of the affective loop should be able to provide satisfactory answers to at least some of the following questions: *Which stimulus (or playful experience) should be presented next*? *When should it be presented*? *Which game elements should be adjusted and how*?

Arguably, we can achieve meaningful adaptation in games because players are prepared for personalised experiences more than in any other form of human-computer interaction. The players' relationship to game adaptation is dependent on their playing style, experience, personality etc., and the form of adaptation (e.g. implicitly or explicitly) needs to comply with the players' needs. So, when creating and designing emotional games, one needs to consider all the processes involved, starting with the game design process itself. Further, while emotion models can be used to inform game designers in a mixed-initiative design fashion (see (Smith, et al., 2011), (Liapis, et al., 2012) among others) we argue that a semi- or fully-automated approach to emotion-driven game design can ultimately lead to improved playing experience. But as the game design entails the definition of many aspects of a game, when referring to emotional game adaptation one fundamental question to ask is *what game elements can one adjust?* In other words: *what does emotional adaptation entail?* A high-level observation of available game elements derives two key classes of adaptable game features: *game agents (and NPCs)* and *game content* (see Figure 1). Both of these can be manipulated to convey emotional responses and adaptation, in a manner that leads the player to become more emotionally involved with the game.

4.1 Adapting and Expressing Emotion through Agents and NPCs

One of the two main ways by which emotions can be manifested in games is through their game characters (see Figure 1). Characters in a game need to act, and their actions should be determined by emotional reactions to events occurring in the game. This can be achieved in a completely scripted manner, or through an automatic, autonomous approach, by using emotional agent architectures (Gratch & Marsella, 2004) underlying cognitive models to generate behaviour of the characters. Such architectures are usually model-based as they seek inspiration from psychological or physiological models of humans, and other species, and embed features that allow them to go beyond the pure "rational" behaviour. Emotional agent architectures naturally include a way to capture emotions or other affective states, such as moods or even personality (Doce, Dias, Prada, & Paiva, 2010). These affective states often have symbolic representations, or can be the resulting pattern of behaviour arising from a variety of different processes embedded in the agent. Examples of these architectures are EMA (Gratch & Marsella, 2004) and FAtiMA, used for research on serious games in the areas of social and emotional training (Paiva, et al., 2004), (Aylett, et al., 2009), (Lim, Dias, Aylett, & Paiva, 2012), ALMA (Gebhard, 2005), or the MindModule (Eladhari & Mateas, 2008) for player characters. Further, these characters may portray social roles and have different personalities leading the users to raise expectations concerning the characters' actions, and as such triggering emotional reactions by the players when those expectations are not met. A game character that plays an ally or a mentor (see (Isbister K. , 2006)) will lead to certain emotional reactions when for example the character deceives the player. The personality of a game character can be established by the nature and strength of the emotions that the character portrays in different situations, and its tendency to act in a certain manner. For example, an extrovert character will use more speech acts and more expressive actions than an introvert character. These features of personality may be achieved by the appropriate parameterization of the agents (see (Doce, Dias, Prada, & Paiva, 2010)).

Characters will not only trigger emotional states as a response to a given situation, but they also need to express emotions in a way that conveys their "internal" emotional state. Thus, emotions not only guide the decision making of the characters, but also the expressions they will portray, which again can be generated in an automatic manner. Expressions of different emotional states, such as for example fear, surprise, sadness or happiness may blend handcrafted animations to express both strong and subtle emotions with procedural animation techniques to achieve real-time behaviour-animated characters (Perlin & Goldberg, 1996).

Characters provide a rich medium to express emotions, trigger emotions and adapt to the emotions of players. Further, these emotional manifestations can be augmented via adaptive narrative and camera profiles (Picardi, Burelli, & Yannakakis, 2011) allowing for the emphasis on particular emotional states or features, and combining it with game content adaptation (see Figure 1). We should, however, stress the research-oriented nature of these early systems acknowledging that autonomous emotional NPCs are still in the realm of a few exploratory research projects. However, we believe that by addressing this challenge, this area will become one of the major pillars of AI in games.

4.2 Adapting and Expressing Emotion through Game Content

Yet, games may or may *not* include agents. Games, however, definitely include a form of virtual environment where agents "live" (if existent) and the interaction is taking place. There are a number of elements (i.e. game content) from the game world that an adaptive process can alter in order to drive the player to particular affective patterns. As mentioned already, game content may include every aspect of the game design such as game rules (Togelius & Schmidhuber, 2008), reward systems, lighting (de Melo & Paiva, 2007), camera profiles (Yannakakis, Martinez, & Jhala, 2010), maps (Togelius, et al., 2010), levels, tracks (Togelius, Yannakakis, Stanley, & Browne, 2011), story plot points (Riedl, 2012), and music (Eladhari, Nieuwdorp, & Fridenfalk, 2006). Even behavioural patterns of NPCs such as their navigation meshes, their parameterised action space and their animations can be viewed as content.

The adaptive process in this case is referred to as *procedural content generation* (PCG) which is the generation of game content via the use of algorithmic means. According to the taxonomy presented in (Togelius, Yannakakis, Stanley, & Browne, 2011) game content can be *necessary* (e.g. game rules) or *optional* (e.g. trees in a level or flying birds on the background). Further, PCG can be either *offline* or *online*, *random* or based on a *parameterised space*, *stochastic* or *deterministic* and finally it can be either *constructive* (i.e. content is generated once) or *generate-and-test* (i.e. content is generated and tested). The Experience-driven PCG framework (Yannakakis & Togelius, 2011) views game content as an indirect building block of player affect and proposes adaptive mechanisms for synthesizing personalised game experiences.

4.3 Integration in the Affective Loop: When and How to Adapt

Once sufficient amounts of appropriate game stimuli (which include the actions of the game characters and stimuli in the environment) have been presented to the player, aspects of the playing experience can be detected and modelled. For the affective loop to close effectively the game logic needs to adapt to the current state of the game-player interaction. Whether agent behaviour or parameterised game content, a mapping is required linking a user's affective state to the game context. That mapping is available as it is essentially the outcome of the emotion modelling phase. Any search algorithm (varying from local and global search to exhaustive search) is applicable for searching in the parameterised search space and finding particular game states (context) that are appropriate for a particular affective state of a specific player. For example, one can envisage the optimization of agent behaviour attributes for maximizing engagement, frustration or empathy towards a player (Leite, et al., 2010). As another example, the study of Shaker et al. (2010) presents the application of exhaustive search for generating *Super Mario Bros* (Nintendo, 1985) levels that are maximally frustrating, engaging or challenging for any player. In that study parameterised game levels are linked to in-game player behaviour attributes and a set of affective states are inferred from crowdsourced player reports. The *model-free* affective model is built via evolving neural networks that learn the crowdsourced pairwise preferences (i.e. neuro-evolutionary preference learning) .

A critical question once an adaptation mechanism is designed is how often particular attributes should be adjusted. The frequency can vary from simple pre-determined or dynamic time windows (Yannakakis & Hallam, 2009) but adaptation can also be activated every time a new level (Shaker, Yannakakis, & Togelius, 2010) or a new game (Yannakakis & and Hallam, 2007) starts, or even after a set of critical player actions – such as in *Façade* (Mateas & Stern, 2003). The time window of adaptation is heavily dependent on the game under examination and the desires of the game designer. Regardless of the time window adopted, adaptation needs to be interwoven well with design if is to be successful.

One approach for assessing the appropriate time window for game adaptation is to test the validity of the emotion models in different time windows and then make a compromise between adaptation frequency and model performance (Yannakakis & Hallam, 2009)). As models are expected to yield lower accuracies the more deviant they are from the interaction time window they were built on, one needs to evaluate their accuracy with respect to different time windows. A good compromise between accuracy and performance would yield sensible decisions about the length of the adaptation time windows. In general, those can be either static across all gameplay or dynamic (dependent on e.g. different levels).

4.4 Evaluating Adaptation

Affective game adaptation can lead to personalised experiences for the player. A key research question, however, is: how do we appropriately evaluate the efficacy of the adaptation mechanism? While several different methods from human factors research are available, all seem to converge to control-based experiments where games are usually evaluated *with* and *without* the adaptation module (e.g. see (Yannakakis & Hallam, 2009) among others). The outcome of such an experimental protocol usually allows concluding whether adaptation seems to have an impact on the player's engagement (or any other relevant emotional state). The efficacy of adaptation can be indirectly measured from standard usability metrics (such as response time), or more directly from the output of the emotional model itself (i.e. testing if adaptation yields higher values for the model's output). In addition, one may perform a user survey that asks players to evaluate the adaptation experience (e.g. see (Yannakakis & Hallam, 2009)).

5 The road ahead

In this final section we list a number of promising research directions for the area of *emotion in games* that, we believe, will contribute to the advancement of the field in the near future.

- **Mixed-initiative experience design**: the mixed-initiative (i.e. human-machine co-creation) approach to design and creativity is getting increasingly important for game design. Innovative projects such as *Sentient Sketchbook* (Liapis, Yannakakis, & Togelius, 2013), *Sketchaworld* (Smelik, 2011) and *Tanagra* (Smith, Whitehead, & Mateas, 2011) have focused on aspects of level design. However, the potential of emotion-driven, mixed-initiative design has not been investigated in depth yet. We believe that co-creative environments which are affected by emotion, intention and preference models (of players and/or designers) may enhance creative thinking in game design.
- **Emotion in the game pipeline:** the impact of emotion in game development can be evident in all phases of game production. Future research needs to focus on establishing protocols for the integration of emotion research in the pipeline of game production. Placing emotion research as the driving force of game production can ultimately lead to better game design, more efficient development, more reliable testing and richer quality assurance.
- **Links to adjacent fields of study:** the study of emotion in games as represented by the AC community can only benefit from stronger links to and collaborations with adjacent research fields which include the areas of game studies, game design, user and user experience research, and experimental psychology. In that way, advances in a field can inform relevant research areas for the better understanding of player emotion and its particularities.
- **Content creation is automated:** the use of procedural content generation techniques for the design of better games has reached a peak of interest in commercial and indie game development which is showcased by successful (almost entirely procedurally generated) games such as *Minecraft* (Mojang, 2011) and *Love* (Eskil Steenberg, 2010). Future games, in general, are expected to contain less manual and more user- or procedurally-generated content as the cost of content creation and the content

creation bottleneck are key challenges for commercial game production. As the number of games that are (partially or fully) automatically generated grows, the challenge of detecting and monitoring emotion in never-ending open worlds of infinite replayability value increases substantially. The automation of content creation, however, offers a unique opportunity towards realizing affect-driven content generation in games (Yannakakis & Togelius, 2011).

- **Multimodal game interaction:** several modalities of player input are still nowadays implausible within commercial game development. For instance, existing techniques for physiological recording require the contact of body parts (e.g. head or fingertips) to the sensors making physiological signals such as EEG, respiration and skin conductance rather impractical and highly intrusive. Modalities such as facial expression and speech could be technically plausible in games even though the majority of the vision-based affect-detection systems currently available cannot operate in real-time (Zeng, Pantic, Roisman, & Huang, 2009). On a positive note, recent advances in sensor technology have resulted in low-cost unobtrusive biofeedback devices appropriate for gaming applications (such as Emotiv[1] EEG system and Empatica[2] bracelet). In addition, top game developers have recently started to experiment with multiple modalities of player input (e.g. physiological and behavioural patterns) for the personalization of experience of popular AAA games such as *Left 4 Dead* (Valve, 2008) (Ambinder, 2011). Finally, recent technology advances in gaming peripherals such as the PrimeSense[3] camera showcase a promising future for multimodal natural interaction in games.
- **General emotions across games**: after sufficient research has been put in the study of emotion in different game genres, methods for recognising emotional manifestations across game genres would be required. Such methods could focus on the inference of generic emotions that are linked to reward systems and game mechanics across game genres.
- **Game data mining:** massive sets of player metrical data (metrics) are currently available and analysed, thus empowering the design of future games (Drachen,

[1] http://emotiv.com
[2] http://www.emoticalab.com
[3] http://www.primesense.com

Thurau, Togelius, Yannakakis, & Bauckhage, 2013). While such data usually contain behavioural aspects of playing experience, data mining and data analysis research will need to focus on inferring the relationship between detailed player metrics, and cognitive and affective maps of experience. Making sense of massive game data sets is amongst the largest challenges from both an analysis and an algorithmic perspective.

Acknowledgements

The authors would like to thank Mirjam P. Eladhari for insightful discussions. This work was supported, in part, by the FP7 ICT project SIREN (project no: 258453).

References

Aarseth, E. (2004). Genre Trouble. In *First Person: New Media as Story, Performance, and Game.* Cambridge: MIT Press.

Ambinder, M. (2011). Biofeedback in Gameplay: How Valve Measures Physiology to Enhance Gaming Experience. *Game Developers Conference.*

Asteriadis, S., Karpouzis, K., & Kollias, S. D. (2008). A neuro-fuzzy approach to user attention recognition. *Proceedings of ICANN*, pp. 927–936.

Aylett, R., Vannini, N., Andre, E., Paiva, A., Enz, S., & Hall, L. (2009). But that was in another country: agents and intercultural empathy. *Proceedings of The 8th International Conference on Autonomous Agents and Multiagent Systems*.

Bates, J. (1994). The role of emotion in believable agents. *Communications of the ACM*, 122-125.

Bhuman, S., & Hingston, P. (2008). Bots trained to play like a human are more fun . *Neural Networks, 2008. IJCNN 2008. IEEE World Congress on Computational Intelligence*.

Calleja, G. (2011). *In-Game: From Immersion to Incorporation.* The MIT Press.

Conati, C. (2002). Probabilistic Assessment of User's Emotions in Educational Games. *Journal of Applied Artificial Intelligence, special issue on "Merging Cognition and Affect in HCI", 16*, 555-575.

Csikszentmihalyi, M. (1990). *Flow: the Psychology of Optimal Experience.* Harper Collins.

de Melo, C., & Paiva, A. (2007). Expression of emotions in virtual humans using lights, shadows, composition and filters. *Affective Computing and Intelligent Interaction*, pp. 546-557.

De Melo, C., Zheng, L., & Gratch, J. (2009). Expression of Moral Emotions in Cooperating Agents. *9th International Conference on Intelligent Virtual Agents*.

Deci, E. L., & Ryan, R. M. (2000). The 'what' and 'why' of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227-268.

Dias, J., & Paiva, A. (2005). Feeling and Reasoning: A Computational Model for Emotional Characters . *Advances in Artificial Intelligence, EPIA*, pp. 127-140.

Doce, T., Dias, J., Prada, R., & Paiva, A. (2010). Creating individual agents through personality traits. *Intelligent Virtual Agents*.

Drachen, A., Thurau, C., Togelius, J., Yannakakis, G., & Bauckhage, C. (2013). Game Data Mining. In *Game Analytics*. Springer-Verlag.

Ekman, P., & Friesen, W. (1978). *Facial Action Coding System: A Technique for the Measurement of Facial Movement.* Palo Alto: Consulting Psychologists Press.

Eladhari, M., & Mateas, M. (2008). Semi-autonomous avatars in World of Minds: A case study of AI-based game design . *Proceedings of the 2008 International Conference on Advances in Computer Entertainment Technology*.

Eladhari, M., Nieuwdorp, R., & Fridenfalk, M. (2006). The soundtrack of your mind: mind music-adaptive audio for game characters . *Proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology*.

Feldman, L. (1995). Valence focus and arousal focus: Individual differences in the structure of affective experience. *Journal of Personality and Social Psychology*(69), 53-166.

Frijda, N. (1986). *The Emotions.* Engelwood cliffs, NJ: Cambridge University Press.

Gebhard, P. (2005, July). ALMA: a layered model of affect. *Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems* , pp. 29-36.

Georgeff, M., Pell, B., Pollack, M., Tambe, M., & Wooldridge, M. (1999). The Belief-Desire-Intention Model of Agency. *Intelligent Agents V: Agents Theories, Architectures, and Languages*, pp. 1-10.

Giannatos, S., Nelson, M., Cheong, Y., & Yannakakis, G. N. (2012). Generating Narrative Action Schemas for Suspense. *Proceedings of the 5th Workshop on Intelligent Narrative Technologies, AIIDE*.

Gomes, P. F., Segura, E. M., Cramer, H., Paiva, T., Paiva, A., & Holmquist, L. E. (2011, November). Vipleo and phypleo: Artificial pet with two embodiments. *Proceedings of the 8th International Conference on Advances in Computer Entertainment*.

Gratch, J., & Marsella, S. (2005). Evaluating a computational model of emotion. *Autonomous Agents and Multi-Agent Systems, 11*(1), 23-43.

Gratch, J., & Marsella, S. (2004). A domain-independent framework for modeling emotion . *Cognitive Systems Research, 5*(4), 269-306.

Hingston, P. (2009). A Turing Test for Computer Game Bots. *IEEE Transactions on Computational Intelligence and AI in Games, I*.

Hullett, K., & Whitehead, J. (2010). Design patterns in FPS levels. *Proceedings of the Fifth International Conference on the Foundations of Digital Games*, pp. 78-85.

Isbister, K. (2006). *Better game characters by design: A psychological approach.* Morgan Kaufmann Pub.

Isbister, K., & Schaffer, N. (2008). *Game Usability: Advancing the Player Experience.* Morgan Kaufman.

Joachims, T. (2002). Optimizing Search Engines using Clickthrough Data . *Proceedings of the ACM Conference on Knowledge Discovery and Data Mining*.

Juul, J. (2001). Games Telling Stories? A brief note on Games and Narratives. *Game Studies, I*(1).

Koster, R. (2005). *A theory of fun for game design.* Paraglyph press.

Lazarus, R. (1994). *Emotion and Adaptation.* Oxford University Press.

Lazzaro, N. (2004). Why we play games: Four keys to more emotion without story. *Game Developers Conference*.

Leite, I., Mascarenhas, S., Pereira, A., Martinho, C., Prada, R., & Paiva, A. (2010). Why Can't We Be Friends? An Empathic Game Companion for Long-Term Interaction. . *In Intelligent Virtual Agents*, pp. 315-321.

Liapis, A., Yannakakis, G. N., & Togelius, J. (2012). Adapting Models of Visual Aesthetics for Personalized Content Creation. *IEEE Transactions on Computational Intelligence and AI in Games, Special Issue on Computational Aesthetics in Games*.

Liapis, A., Yannakakis, G. N., & Togelius, J. (2013). Sentient Sketchbook: Computer-Aided Game Level Authoring. *Proceedings of ACM Conference on Foundations of Digital Games*, pp. 213-220.

Lim, M. Y., Dias, J., Aylett, R., & Paiva, A. (2012). Creating adaptive affective autonomous NPCs. *Autonomous Agents and Multi-Agent Systems*, pp. 1-25.

Malone, T. W. (1980). What makes things fun to learn? heuristics for designing instructional computer games. *Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems*, pp. 162-169.

Mandryk, R., & Inkpen, K. (2004). Physiological indicators for the evaluation of co-located collaborative play. *Proceedings of the 2004 ACM conference on Computer supported cooperative work.* ACM.

Martinez, H. P., & Yannakakis, G. N. (2011). Mining Multimodal Sequential Patterns: A Case Study on Affect Detection. *Proceedings of the 13th International Conference on Multimodal Interaction (ICMI)* .

Martinez, H. P., Hullett, K., & Yannakakis, G. N. (2010). Extending Neuro-evolutionary Preference Learning through Player Modeling. *Proceedings of the 2010 IEEE Conference on Computational Intelligence and Games*, pp. 313-320.

Mateas, M., & Stern, A. (2003). Façade: An Experiment in Building a Fully-Realized Interactive Drama. *Game Developers Conference, Game Design track*.

McCoy, J., Treanor, M., Samuel, B., Tearse, B., Mateas, M., & N., W.-F. (2010). Comme il Faut 2: a fully realized model for socially-oriented gameplay. *INT3 '10: Proceedings of the Intelligent Narrative Technologies III Workshop*, pp. 1-8.

McQuiggan, S., & Lester, J. (2009). Modeling Affect Expression and Recognition in an Interactive Learning Environment. *International Journal of Learning Technology, IV*(3), 216-233.

McQuiggan, S., Robison, J., & Lester, J. (2010). Affective Transitions in Narrative-Centered Learning Environments. *Educational Technology & Society, I*(13), 40-53.

Nijholt, A. (2009). BCI for Games: A State of the Art Survey. *Proceedings of Entertainment Computing - ICEC*, pp. 225–228.

Ortony, A., Clore, G., & Collins, A. (1988). *The Cognitive Structure of Emotions.* Cambridge University Press.

Paiva, A., Dias, J., Sobral, S., Aylett, R., Sobreperez, S., Woods, S., . . . Hall, L. E. (2004). Caring for Agents and Agents that Care: Building Empathic Relations with Synthetic Agents. *Autonomous Agents and Multi-agent Systems, AAMAS*.

Pantic, M., & Caridakis, G. (2011). Image and Video Processing for Affective Applications. In *Emotion-Oriented Systems: The Humaine Handbook* (pp. 101–117). Springer-Verlag Berlin Heidelberg.

Perlin, K., & Goldberg, A. (1996). Improv: A system for scripting interactive actors in virtual worlds. *Proceedings of the 23rd annual conference on Computer graphics and interactive techniques*, pp. 205-216.

Picardi, A., Burelli, P., & Yannakakis, G. N. (2011). Modelling virtual camera behaviour through player gaze. *Proceedings of the 6th International Conference on Foundations of Digital Games*, pp. 107-114.

Plans, D., & Morelli, D. (2012). Experience-Driven Procedural Music Generation for Games. *IEEE Transactions on Computational Intelligence and AI in Games, IV*(3), 192-198.

Poels, K., & IJsselsteijn, W. (2008). Development and validation of the game experience questionnaire. *FUGA Workshop mini-symposium*.

Riedl, M. O. (2012). Interactive Narrative: A Novel Application of Artificial Intelligence for Computer Games. *Proceedings of the 26th AAAI Conference on Artificial Intelligence*.

Roberts, D., H., N., & C., I. (2009). Learning to Influence Emotional Responses for Interactive Storytelling. *AAAI Symposium on Intelligent Narrative Technologies*.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*(6), 1161-1178.

Salen, K., & Zimmerman, E. (2003). *Rules of Play: Game Design Fundamentals.* MIT Press.

Savva, N., Scarinzi, A., & Bianchi-Berthouze, N. (2012). Continuous Recognition of Player's Affective Body Expression as Dynamic Quality of Aesthetic Experience. *IEEE Transactions on CI and AI in Games, Special Issue on Computational Creativity*, 199 - 212.

Scherer, K. R. (1993). Studying the emotion-antecedent appraisal process: An expert system approach . *Cognition and Emotion, VII*, 325-355.

Scherer, K. R. (2005). What are emotions? And how can they be measured? *Social Science Information, IV*(44), 693-727.

Seif, E.-N. M., Vasilakos, T., C., R., & Zupko, J. (2009). Dynamic Intelligent Lighting for Directing Visual Attention in Interactive 3D Scenes. *IEEE Transactions on Computational Intelligence and AI in Games*, *I*(2).

Shaker, N., Asteriadis, S., Yannakakis, G. N., & Karpouzis, K. (2011). A Game-based Corpus for Analysing the Interplay between Game Context and Player Experience. *Proceedings of the 2011 Affective Computing and Intelligent Interaction Conference; Emotion in Games Workshop*.

Shaker, N., Yannakakis, G. N., & Togelius, J. (2010). Towards automatic personalized content generation for platform games. *AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment (AIIDE)*.

Skinner, B. F. (1938). *The Behavior of Organisms: An Experimental Analysis.* Cambridge, Massachusetts: B. F. Skinner Foundation.

Smelik, R. M. (2011). *A Declarative Approach to Procedural Generation of Virtual Worlds.* PhD Thesis, Delft University of Technology, Delft.

Smith, G., Whitehead, J., & Mateas, M. (2011). Tanagra: Reactive Planning and Constraint Solving for Mixed-Initiative Level Design. *IEEE Transactions on Computational Intelligence and AI in Games*.

Suits, B. (2005). *The Grasshopper: Games, Life and Utopia.* Broadview Press.

Sundstrom, P. (2005). *Exploring the affective loop.* Stockholm University.

Sweetser, P., & Wyeth, P. (2005). GameFlow: A Model for Evaluating Player Enjoyment in Games. *ACM Computers in Entertainment, III*(3).

Thomas, F., & Johnston, O. (1995). The illusion of life: Disney animation. . *Hyperion*.

Togelius, J., & Schmidhuber, J. (2008). An Experiment in Automatic Game Design. *Proceedings of the IEEE Symposium on Computational Intelligence and Games (CIG)*, pp. 111-118.

Togelius, J., Preuss, M., Beume, N., Wessing, S., Hagelback, J., & Yannakakis, G. N. (2010). Multiobjective exploration of the starcraft map space. *2010 IEEE Conference on In Computational Intelligence and Games (CIG)*, pp. 265-272.

Togelius, J., Yannakakis, G. N., Stanley, K. O., & Browne, C. (2011). Search-based Procedural Content Generation: A Taxonomy and Survey. *IEEE Transactions on Computational Intelligence and AI in Games, Special Issue on Procedural Content Generation, III*(3), 172-186.

Tognetti, S., Garbarino, M., Bonarini, A., & Mateucci, M. (2010). Modeling enjoyment preferecne from physiological responses in a car racing game. *Proceedings of the IEEE Conference on Computational Intelligence and Games*, pp. 321-328.

Yannakakis, G. N. (2009). Preference Learning for Affective Modeling. *Proceedings of the Int. Conf. on Affective Computing and Intelligent Interaction*, pp. 126-131.

Yannakakis, G. N. (2012). Game AI Revisited. *ACM Computing Frontiers Conference*, pp. 285-292.

Yannakakis, G. N., & and Hallam, J. (2007). Towards Optimizing Entertainment in Computer Games. *Applied Artificial Intelligence*(21), 933-971.

Yannakakis, G. N., & Hallam, J. (2009, June). Real-time Game Adaptation for Optimizing Player Satisfaction. *IEEE Transactions on Computational Intelligence and AI in Games, I*(2), 121-133.

Yannakakis, G. N., & Hallam, J. (2011). Rating vs. Preference: a comparative study of self-reporting. *Affective Computing and Intelligent Interaction*, pp. 437-446.

Yannakakis, G. N., & Togelius, J. (2011). Experience-driven Procedural Content Generation. *IEEE Transactions on Affective Computing, II*(3), 147-161.

Yannakakis, G. N., Martinez, H. P., & Jhala, A. (2010). Towards Affective Camera Control in Games. *User Modeling and User-Adapted Interaction, IV*(20), 313-340.

Yannakakis, G. N., Togelius, J., Khaled, R., Jhala, A., Karpouzis, K., Paiva, A., & Vasalou, A. (2010). Siren: Towards adaptive serious games for teaching conflict resolution. *Proceedings of the 4th European Conference on Games Based Learning*.

Zeng, Z., Pantic, M., Roisman, G., & Huang, T. (2009). A survey of affect recognition methods: Audio, visual, and spontaneous expressions. *IEEE Trans. Pattern Analysis and Machine Intelligence, I*(31), 39-58.