# How to Model and Augment Player Satisfaction: A Review

Georgios N. Yannakakis
Center for Computer Games Research
IT-University of Copenhagen
Rued Langgaards Vej 7
DK-2300 Copenhagen S
yannakakis@itu.dk

## ABSTRACT

This is a review on approaches for modeling satisfaction perceived by users interacting with entertainment systems. Experimental studies with adult and children users of games (screen-based and physical-interactive) are outlined and the most promising approaches for augmenting player satisfaction while the game is played (i.e. in real-time) are discussed.

## 1. INTRODUCTION

Cognitive user models of playing experience promise significant potential for the design of digital interactive entertainment systems such as screen-based computer or augmented-reality physical games. Quantitatively modeling entertainment or satisfaction — *fun*, *player satisfaction* and *entertainment* will be used interchangeably in this paper — as a class of user experiences may reveal game features or user features of play that relate to the level of satisfaction perceived by the user (player). That relationship can then be used to adjust digital entertainment systems according to individual user preferences to optimize player satisfaction in real-time.

This paper reviews the state-of-the-art literature on qualitative and quantitative approaches to player satisfaction modeling derived from studies with children and adult users. Approaches covered include design and construction of both cognitive and affective models for capturing entertainment. Moreover, the promise of real-time adaptive techniques for optimizing entertainment of the user in real-time is outlined and open research questions in entertainment modeling and augmentation are discussed.

## 2. ENTERTAINMENT MODELING AND OPTIMIZATION

We classify approaches for capturing the level of player satisfaction into *qualitative* and *quantitative*. The first includes qualitative features and criteria that collectively contribute to engaging experiences in entertainment systems, derived from experimental psychology studies; the latter includes studies for quantifying the reported qualitative criteria of entertainment and constructing models that quantify (in some appropriate way) the complicated mental state of satisfaction perceived while interacting with digital interactive systems [1]. Work on methodologies for improving player satisfaction in real-time is presented at the end of this section.

### 2.1 Qualitative Approaches

Several researchers have been motivated to identify what is 'fun' in a game and what engages people playing computer games. Psychological approaches include Malone's principles of intrinsic qualitative factors for engaging game play [22], namely *challenge*, *curiosity* and *fantasy*, as well as the well-known concepts of the theory of *flow* [10]. Incorporating flow in computer games as a model for evaluating player enjoyment has been a focus of few studies [34, 9]. A comprehensive review of the literature on qualitative approaches for modeling player enjoyment demonstrates a tendency for proposed criteria to overlap with Malone's and Csikszentmihalyi's foundational concepts. An example of such an approach is Lazzaro's work on 'fun' clustering [19]. Lazzaro focuses on four entertainment factors derived from facial expressions and data obtained from game surveys on players: hard fun, easy fun, altered states and socialization. Koster's theory of fun [18], which is primarily inspired by Lazzaro's four factors, defines 'fun' as the act of mastering the game mentally. An alternative approach to fun capture is presented in [30] where fun is composed of three dimensions: endurability, engagement and expectations.

A few indicative studies among the vast literature of the *user and game experience* field are considered in this section. The work of Pagulayan et al. [27, 26] provides an extensive outline of game testing methods for effective user-centered design of games that generate enjoyable experiences. Ijsselstein et al. [17] describe the challenge of adequately characterizing and measuring experiences associated with playing digital games and highlight the concepts of *immersion* [7] and *flow* [10] as potential candidates for evaluating gameplay. Ryan et al. [32] have considered human motivation of play in virtual worlds, attempting to relate it to player satisfaction. Their survey experiments demonstrate that perceived in-game autonomy and competence are associated with game enjoyment.

Vorderer et al. [39] present an analysis of the impact of competition (i.e. challenge) on entertainment and identify challenge as the most important determinant of the enjoyment perceived by video game (*Tomb Raider*) players. They claim that successful completion of a task generates sympathetic arousal — especially when the challenge of the task matches the player's abilities, which is consistent with the *flow* concept [11]. Finally, according to Choi et al. [8], challenge and satisfaction appear as independent processes, in contrast to the views of Malone [22] and Yannakakis et al.

[54] where satisfaction derives from the appropriate level of challenge and other game components.

All the above-mentioned studies are based on either empirical observations or on linear correlations of user input (interaction and physiological data) with reported emotions derived from Likert scale questionnaires. On the other hand, the quantitative approaches presented in the following section attempt to formulate entertainment in mathematical models which yield reliable numerical values for 'fun', entertainment or excitement.

## 2.2 Quantitative approaches

Advances in quantitative player satisfaction modeling have established a growing community of researchers that investigate dissimilar methodologies for modeling and improving gameplay experience [1]. Generated cognitive and affective modeling approaches are classified here according to the input source data used for building the models: player-game interaction or physiological data.

### 2.2.1 Player-Game Interaction Data

Iida's work on metrics of entertainment in board games is considered pioneering, being the first attempt at modeling 'fun' quantitatively. He introduced a general metric of entertainment for variants of chess games, based on average game length and possible moves [16]. Other work in the field of quantitative entertainment capture is based on the hypothesis that the player-opponent interaction — rather than the audiovisual features, the context or the genre of the game — is the property that contributes the majority of the quality features of entertainment in a computer game [40]. Given this fundamental assumption, a metric for measuring the real time entertainment value of predator/prey games was designed, using quantitative estimators of game characteristics (such as challenge and curiosity) based on the player-game interaction. The developed metric was established as efficient and reliable by validation against human judgement [48, 41]. Further experimental survey studies by Beume et al. [4, 5] demonstrate the generality of the proposed interest metric in different prey/predator game variants. A quantitative measure of *flow* derived from subject's perceived gameplay duration is introduced in those studies.

Additional experiments [44] have shown that artificial neural networks and fuzzy neural networks can extract a better estimator of player satisfaction than a human-designed one, given appropriate estimators of the challenge and curiosity of the game and data on human players' preferences [47]. Those studies introduce the notion of *comparative fun analysis*, opposed to Likert scale, for eliciting genuine and subjective complex notions like 'fun' and 'enjoyment' out of test subjects. Using 2-alternative forced choice survey questions — e.g. 'which of these two games was more fun to play?' — minimizes the assumptions made about subject's notions of 'fun' and allows a fair comparison between the answers of different subjects. The reliability of comparative fun analysis is shown through the highly accurate entertainment models generated in both screen-based [47] and physical game test-beds [46].

### 2.2.2 Physiological Data

A further step toward entertainment capture is to equip games with richer human-computer interaction through affect recognizers which are able to identify correlations between physiological signals and the human notion of entertainment. Measurements of physiological quantities have been used extensively within the affective computing research area for emotion recognition in children and adults. Heart rate (HR) signals have been monitored to effect discrimination between children's exploration, problem-solving and play tasks [6]. Experiments with two-year old children further showed suppression of heart rate variability (HRV) during exploration, and solution of a puzzle, suggesting that the task demands for these two activities were greater than those during play [14].

Correlations between physiological signals — galvanic skin response (GSR), jaw electromyography (EMG), respiration and cardiovascular measures — and reported adult user experiences in computer games have been examined by Mandryk et al. [24]. In [23], a fuzzy model with rules grounded in psychophysiology theory indicates that high arousal and positive valence (a combination corresponding to 'fun' and excitement) is present when HR and GSR are high and the jaw electromyography corresponds to a smiling player. Working on the same basis as Mandryk et al. [24], Ravaja et al. [29] examined whether the nature of the game opponent influences the physiological state of players. In addition, Hazlett's [13] work focused on the use of facial EMG to distinguish positive and negative emotional valence during interaction with a racing video game. Moreover, Rani et al. [28] propose a methodology for detecting the anxiety level of the player and appropriately adjusting the level of challenge (e.g. speed) in the game of 'Pong'. Physiological state (hear-rate, galvanic skin response) prediction models have also been proposed for potential entertainment augmentation in computer games [25].

All of the studies referred to above use physiological measurements for capturing user experiences (e.g. 'fun', engagement or excitement) applied within the computer and edutainment games framework. Experiments by Yannakakis et al. [51, 52, 45, 49] have distinguished those features of HR, skin conductance (SC) and blood volume pulse (BVP) signal recordings of children attributed to entertainment from those features that correspond to pure physical activity in action games played in interactive physical playgrounds. In those studies, highly accurate subjective models (predictors of entertainment preferences) of reported 'fun' grounded in statistical features of physiological signal dynamics were constructed.

## 2.3 Optimizing Player Satisfaction

Approaches towards optimizing player satisfaction can be classified as *implicit* or *explicit*. Within the first class of approaches we meet use of machine learning techniques for adjusting a game's difficulty — based on the assumption that challenge is the only factor that contributes to enjoyable gaming experiences — which implies entertainment augmentation. Such approaches include applications of reinforcement learning [2], genetic algorithms [38], probabilistic models [15] and dynamic scripting [33, 20]. Moreover, user models have been constructed for the generation of adaptive interactive narrative systems that potentially optimize the

experience of the user [3, 31, 35]. User preference modeling towards content (race track) creation in racing games has also shown a potential for enhancing the quality of playing experience in those games [36, 37]. However, human survey experiments verifying the assumption that player satisfaction is enhanced have not been reported in all aforementioned approaches.

Within the *explicit* methods for optimizing player satisfaction, robust adaptive learning mechanisms have been built to optimize the human-verified ad-hoc 'interest' (entertainment) metric for prey/predator games introduced in [40, 48]. Experiments showed that an on-line neuro-evolution mechanism [41, 42, 43, 53] and a player modeling technique through Bayesian learning [55] were each capable of maintaining or increasing the game's entertainment value while the game was being played. Effectiveness and robustness of the adaptive (neuro-evolution) learning mechanism in real-time has been evaluated via human survey experiments [48]. Furthermore, studies with the "Playware" [21] augmented-reality playground have shown that ad-hoc rule-based mechanisms [12], and gradient search approaches [50] applied to artificial neural network entertainment models [46], can successfully adapt a physical interactive game in real-time according to a user's individual play features and improve children's gameplay experience.

## 3. DISCUSSION

The limitations of the quantitative approaches to entertainment modeling lie in the complexity of entertainment as a mental state. The generated entertainment values cannot be regarded as a mental cognitive or affective state approximators but should be viewed rather as numerical correlates of expressed user entertainment preferences. These correlates, however, serve the purpose of capturing the human notion of perceived satisfaction for generating enjoyable playing experiences.

The existing *explicit* mechanisms for improving player satisfaction in real-time can be used as baseline approaches for future implementations of adaptive learning in games. The next obvious step is the use of more sophisticated machine learning tools (most likely via reinforcement learning) for augmenting player satisfaction in real-time. Current state-of-the-art indicates that modeling player satisfaction, in simple games at least (e.g. arcade and augmented-reality games for children), is possible. The key open question that remains is whether such approaches can scale up to commercial-standard complex screen-based and/or physical games. Future research endeavors in that direction will exploit the promise of the player satisfaction modeling field and provide further insight to human notion of gameplay entertainment.

## 4. ACKNOWLEDGMENTS

## 5. REFERENCES

[1] IEEE Task Force on Player Satisfaction Modeling. IEEE Computational Intelligence Society, 2007. Available at http://game.itu.dk/PSM/.

[2] G. Andrade, G. Ramalho, H. Santana, and V. Corruble. Extending reinforcement learning to provide dynamic game balancing. In *Proceedings of the Workshop on Reasoning, Representation, and Learning in Computer Games, 19th International Joint Conference on Artificial Intelligence (IJCAI)*, pages 7–12, August 2005.

[3] H. Barber and D. Kudenko. A user model for the generation of dilemma-based interactive narratives. In G. N. Yannakakis and J. Hallam, editors, *Proceedings of the AIIDE'07 Workshop on Optimizing Player Satisfaction, Technical Report WS-07-01*, pages 13–18. AAAI Press, 2007.

[4] N. Beume, H. Danielsiek, C. Eichhorn, B. Naujoks, M. Preuss, K. Stiller, and S. Wessing. Measuring Flow as Concept for Detecting Game Fun in the Pac-Man Game. In *Proc. 2008 Congress on Evolutionary Computation (CEC'08) within Fifth IEEE World Congress on Computational Intelligence (WCCI'08)*. IEEE, 2008.

[5] N. Beume, T. Hein, B. Naujoks, G. Neugebauer, N. Piatkowski, M. Preuss, R. Stoer, and A. Thom. To Model or Not to Model: Controlling Pac-Man Ghosts Without Incorporating Global Knowledge. In *Proc. 2008 Congress on Evolutionary Computation (CEC'08) within Fifth IEEE World Congress on Computational Intelligence (WCCI'08)*. IEEE, 2008.

[6] C. Hutt. *Exploration and play, in Play and learning*, pages 175–194. Gardner Press: New York, 1979.

[7] G. Calleja. *Digital Games as Designed Experience: Reframing the Concept of Immersion*. PhD thesis, Victoria University of Wellington, New Zealand, 2007.

[8] D. Choi, H. Kim, and J. Kim. Toward the construction of fun computer games: Differences in the views of developers and players. *Personal Technologies*, 3(3):92–104, September 1999.

[9] B. Cowley, D. Charles, M. Black, and R. Hickey. Toward an Understanding of Flow in Video Games. *ACM Computers in Entertainment*, 6(2), July 2008.

[10] M. Csikszentmihalyi. *Flow: The Psychology of Optimal Experience*. New York: Harper & Row, 1990.

[11] M. Csikszentmihalyi. *Beyond Boredom and Anxiety: Experiencing Flow in Work and Play*. San Francisco: Jossey-Bass, 2000.

[12] F. Hammer, A. Derakhshan, and H. H. Lund. Adapting Playgrounds for Children Play using Ambient Playware. In *Proceedings of the 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROSŠ06)*, pages 5625–5630, Beijing, China, October 9–15 2006.

[13] R. L. Hazlett. Measuring emotional valence during interactive experiences: boys at video game play. In *CHI '06: Proceedings of the SIGCHI conference on Human Factors in computing systems*, pages 1023–1026, New York, NY, USA, 2006. ACM Press.

[14] M. Hughes and C. Hutt. Heart-rate correlates of childhood activities: play, exploration, problem-solving and day-dreaming. *American Psychologist*, 8(4):253–263, 1979.

[15] R. Hunicke and V. Chapman. AI for Dynamic Difficulty Adjustment in Games. In *Proceedings of the Challenges in Game AI Workshop, 19th Nineteenth*

*National Conference on Artificial Intelligence (AAAI'04)*, 2004.

[16] H. Iida, N. Takeshita, and J. Yoshimura. A metric for entertainment of boardgames: its implication for evolution of chess variants. In R. Nakatsu and J. Hoshino, editors, *IWEC2002 Proceedings*, pages 65–72. Kluwer, 2003.

[17] W. A. Ijsselsteijn, Y. A. W. de Kort, K. Poels, A. Jurgelionis, and F. Belotti. Characterising and measuring user experiences. In *ACE 2007 International Conference on Advances in Computer Entertainment Technology*, 2007.

[18] R. Koster. *A Theory of Fun for Game Design.* Paraglyph Press, 2005.

[19] N. Lazzaro. Why we play games: Four keys to more emotion without story. Technical report, XEO Design Inc., 2004.

[20] J. Ludwig and A. Farley. A learning infrastructure for improving agent performance and game balance. In G. N. Yannakakis and J. Hallam, editors, *Proceedings of the AIIDE'07 Workshop on Optimizing Player Satisfaction, Technical Report WS-07-01*, pages 7–12. AAAI Press, 2007.

[21] H. H. Lund, T. Klitbo, and C. Jessen. Playware technology for physically activating play. *Artifical Life and Robotics Journal*, 9(4):165–174, 2005.

[22] T. W. Malone. What makes computer games fun? *Byte*, 6:258–277, 1981.

[23] R. L. Mandryk and M. S. Atkins. A Fuzzy Physiological Approach for Continuously Modeling Emotion During Interaction with Play Environments. *International Journal of Human-Computer Studies*, 65:329–347, 2007.

[24] R. L. Mandryk, K. M. Inkpen, and T. W. Calvert. Using Psychophysiological Techniques to Measure User Experience with Entertainment Technologies. *Behaviour and Information Technology (Special Issue on User Experience)*, 25(2):141–158, 2006.

[25] S. McQuiggan, S. Lee, and J. Lester. Predicting User Physiological Response for Interactive Environments: An Inductive Approach. In *Proceedings of the 2nd Artificial Intelligence for Interactive Digital Entertainment Conference*, pages 60–65, 2006.

[26] R. J. Pagulayan and K. Keeker. *Handbook of Formal and Informal Interaction Design Methods*, chapter Measuring Pleasure and Fun: Playtesting. San Francisco: Morgan Kaufmann Publishers, 2007.

[27] R. J. Pagulayan, K. Keeker, D. Wixon, R. L. Romero, and T. Fuller. *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications*, chapter User-centered design in games, pages 883–906. NJ: Lawrence Erlbaum Associates, 2003.

[28] P. Rani, N. Sarkar, and C. Liu. Maintaining optimal challenge in computer games through real-time physiological feedback. In *Proceedings of the 11th International Conference on Human Computer Interaction*, 2005.

[29] N. Ravaja, T. Saari, M. Turpeinen, J. Laarni, M. Salminen, and M. Kivikangas. Spatial Presence and Emotions during Video Game Playing: Does It Matter with Whom You Play? *Presence Teleoperators & Virtual Environments*, 15(4):381–392, 2006.

[30] J. Read, S. MacFarlane, and C. Cassey. Endurability, engagement and expectations. In *Proceedings of International Conference for Interaction Design and Children*, 2002.

[31] D. L. Roberts, C. R. Strong, and C. L. Isbell. Estimating player satisfaction through the author's eyes. In G. N. Yannakakis and J. Hallam, editors, *Proceedings of the AIIDE'07 Workshop on Optimizing Player Satisfaction, Technical Report WS-07-01*, pages 31–36. AAAI Press, 2007.

[32] R. M. Ryan, C. S. Rigby, and A. Przybylski. The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion*, 30(4):344–360, 2006.

[33] P. Spronck, I. Sprinkhuizen-Kuyper, and E. Postma. Difficulty Scaling of Game AI. In *Proceedings of the 5th International Conference on Intelligent Games and Simulation (GAME-ON 2004)*, pages 33–37, 2004.

[34] P. Sweetser and P. Wyeth. GameFlow: A Model for Evaluating Player Enjoyment in Games. *ACM Computers in Entertainment*, 3(3), July 2005.

[35] D. Thue, V. Bulitko, M. Spetch, and E. Wasylishen. Learning player preferences to inform delayed authoring. In *Papers from the AAAI'07 Fall Symposium on Intelligent Narrative Technologies.* AAAI Press, 2007.

[36] J. Togelius, R. D. Nardi, and S. M. Lucas. Making racing fun through player modeling and track evolution. In G. N. Yannakakis and J. Hallam, editors, *Proceedings of the SAB Workshop on Adaptive Approaches to Optimizing Player Satisfaction*, pages 61–70, Rome, 2006.

[37] J. Togelius, R. D. Nardi, and S. M. Lucas. Towards automatic personalised content creation for racing games. In *Proceedings of the IEEE Symposium on Computational Intelligence and Games*, pages 252–259, Hawaii, USA, April 2007. IEEE.

[38] M. A. Verma and P. W. McOwan. An adaptive methodology for synthesising Mobile Phone Games using Genetic Algorithms. In *Congress on Evolutionary Computation (CEC-05)*, pages 528–535, Edinburgh, UK, September 2005.

[39] P. Vorderer, T. Hartmann, and C. Klimmt. Explaining the enjoyment of playing video games: the role of competition. In D. Marinelli, editor, *ICEC conference proceedings 2003: Essays on the future of interactive entertainment*, pages 107–120, Pittsburgh. Carnegie Mellon University Press.

[40] G. N. Yannakakis and J. Hallam. Evolving Opponents for Interesting Interactive Computer Games. In S. Schaal, A. Ijspeert, A. Billard, S. Vijayakumar, J. Hallam, and J.-A. Meyer, editors, *From Animals to Animats 8: Proceedings of the 8th International Conference on Simulation of Adaptive Behavior (SAB-04)*, pages 499–508, Santa Monica, LA, CA, July 2004. The MIT Press.

[41] G. N. Yannakakis and J. Hallam. A Generic Approach for Obtaining Higher Entertainment in Predator/Prey Computer Games. *Journal of Game Development*, 1(3):23–50, December 2005.

[42] G. N. Yannakakis and J. Hallam. A generic approach

for generating interesting interactive pac-man opponents. In G. Kendall and S. M. Lucas, editors, *Proceedings of the IEEE Symposium on Computational Intelligence and Games*, pages 94–101, Essex University, Colchester, UK, 4–6 April 2005.

[43] G. N. Yannakakis and J. Hallam. A scheme for creating digital entertainment with substance. In *Proceedings of the Workshop on Reasoning, Representation, and Learning in Computer Games, 19th International Joint Conference on Artificial Intelligence (IJCAI)*, pages 119–124, August 2005.

[44] G. N. Yannakakis and J. Hallam. Towards Capturing and Enhancing Entertainment in Computer Games. In *Proceedings of the 4th Hellenic Conference on Artificial Intelligence, Lecture Notes in Artificial Intelligence*, volume 3955, pages 432–442, Heraklion, Greece, May 2006. Springer-Verlag.

[45] G. N. Yannakakis and J. Hallam. Entertainment Modeling in Physical Play through Physiology beyond Heart-Rate. In A. Paiva, R. Prada, and R. Picard, editors, *Proceedings of the International Conference on Affective Computing and Intelligent Interaction, LNCS 4738*, pages 256–267, Lisbon, Portugal, September 2007. Springer-Verlag.

[46] G. N. Yannakakis and J. Hallam. Game and Player Feature Selection for Entertainment Capture. In *Proceedings of the IEEE Symposium on Computational Intelligence and Games*, pages 244–251, Hawaii, USA, April 2007. IEEE.

[47] G. N. Yannakakis and J. Hallam. Modeling and augmenting game entertainment through challenge and curiosity. *International Journal on Artificial Intelligence Tools*, 16(6):981–999, December 2007.

[48] G. N. Yannakakis and J. Hallam. Towards Optimizing Entertainment in Computer Games. *Applied Artificial Intelligence*, 21:933–971, 2007.

[49] G. N. Yannakakis and J. Hallam. Entertainment Modeling through Physiology in Physical Play. *International Journal of Human-Computer Studies*, 66:741–755, October 2008.

[50] G. N. Yannakakis and J. Hallam. Real-time Adaptation of Augmented-Reality Games for Optimizing Player Satisfaction. In *Proceedings of the IEEE Symposium on Computational Intelligence and Games*, Perth, Australia, December 2008. IEEE.

[51] G. N. Yannakakis, J. Hallam, and H. H. Lund. Capturing Entertainment through Heart-rate Dynamics in the Playware Playground. In *Proceedings of the 5th International Conference on Entertainment Computing, Lecture Notes in Computer Science*, volume 4161, pages 314–317, Cambridge, UK, 2006. Springer-Verlag.

[52] G. N. Yannakakis, J. Hallam, and H. H. Lund. Entertainment Capture through Heart Rate Activity in Physical Interactive Playgrounds. *User Modeling and User-Adapted Interaction, Special Issue: Affective Modeling and Adaptation*, 18(1-2):207–243, February 2008.

[53] G. N. Yannakakis, J. Levine, and J. Hallam. An Evolutionary Approach for Interactive Computer Games. In *Proceedings of the Congress on Evolutionary Computation (CEC-04)*, pages 986–993, June 2004.

[54] G. N. Yannakakis, H. H. Lund, and J. Hallam. Modeling Children's Entertainment in the Playware Playground. In *Proceedings of the IEEE Symposium on Computational Intelligence and Games*, pages 134–141, Reno, USA, May 2006. IEEE.

[55] G. N. Yannakakis and M. Maragoudakis. Player modeling impact on player's entertainment in computer games. In *Proceedings of the 10th International Conference on User Modeling; Lecture Notes in Computer Science*, volume 3538, pages 74–78, Edinburgh, 24–30 July 2005. Springer-Verlag.