Comparative Fun Analysis in the Innovative Playware Game Platform

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Abstract

This paper presents comparative fun experiments in the innovative playground 'Playware' which is a combination of physical and virtual components for activating physical and social children's play. For this purpose, a quantitative approach to entertainment modeling based on psychological studies in the field of computer games is introduced. The paper investigates quantitatively how the qualitative factors of *challenge*, *curiosity* and *fantasy* contribute to children's entertainment when playing Playware games. Statistical analysis of children's self-reports shows that objectively children's notion of entertainment correlates highly with the *fantasy* factor whereas desired levels of *challenge* and *curiosity* depend on the individual child's requirements.

Keywords

Intelligent interactive physical playgrounds, comparative fun analysis, children.

ACM Classification Keywords

H.5.2. [User Interfaces] Evaluation/methodology, User-Centered design. H.5.1. [Multimedia Information Systems] Artificial, augmented, and virtual realities. H.1.2 [User/Machine Systems] Human factors. I.2.0 [General] Cognitive simulation.

Introduction

Cognitive modeling within human-computer interactive systems is a prominent area of research. Computer games, as examples of such systems, provide an ideal environment for this research since they embed rich forms of interactivity between humans and non-player characters (NPC's). Being able to capture quantitatively the level of user (gamer) engagement or satisfaction in real-time can grant insights to the appropriate intelligent methodology for enhancing the quality of playing experience [15] and furthermore be used to adjust digital entertainment environments according to individual user preferences.

Features of computer games that keep children (among others) engaged more than other digital media include their high degree of interactivity and the freedom for the child to develop and play a role within a fantasy world which is created during play [8]. On the other hand, traditional playgrounds offer the advantage of physical play, which furthermore improves the child's health condition, augment children's ability to engage in social and fantasy play [4] and provide the freedom for children to generate their own rules on their own developed games. The 'Playware' [7] intelligent interactive physical playground attempts to combine the aforementioned features of both worlds: computer games and traditional playgrounds. This innovative platform will be described comprehensively and experiments with children on developed Playware games will be introduced in this paper.

Motivated by the lack of quantitative models of entertainment, an endeavor for capturing child satisfaction in real-time through Malone's qualitative factors for engaging gameplay [8], namely *challenge* (i.e. *'provide a goal whose attainment is uncertain'*), *curiosity* (i.e. *'what will happen next in the game?'*) and *fantasy* (i.e. *'show or evoke images of physical objects or social situations not actually present'*) is introduced in the work presented here. In this work, we define entertainment primarily as the level of satisfaction generated by the real-time player-game opponent interaction — by 'opponent' we define any controllable interactive feature of the game. According to this approach, a game is primarily a learning process and the level of entertainment is kept high when game opponents enable new learning patterns (*'not too easy game'*) for the player that can be perceived and learned by the player (*'not too difficult game'*) [3, 16].

Results demonstrate that fantasy of a given game is correlated highly with the children's notion of entertainment for this game. Moreover, we show that the levels of challenge and curiosity have a subjective effect in a child's entertainment since each child has individual requirements as far as these two factors are concerned. The limitations of the proposed methodology and its extensibility to other genres of digital entertainment are discussed as well as its general use as an efficient baseline for intelligent game design is outlined.

Capturing Fun

There have been several psychological studies to identify what is "fun" in a game and what engages people playing computer games. Theoretical approaches include Malone's principles of intrinsic qualitative factors for engaging gameplay [8] and the well-known concepts of the theory of *flow* (*'flow is the mental state in which players are so involved in the game that nothing else matters'*) [2]. Other qualitative studies include Lazzaro's "fun" clustering — based on Malone's categorization — on four entertainment factors based on facial expressions and data obtained from game surveys on players [5]. Koster's [3] *theory of fun*, which is primarily inspired by Lazzaro's four factors, defines "fun" as the act of mastering the game mentally.

Previous 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 primarily contributes the majority of the quality features of entertainment in a computer game [19]. Based on this fundamental assumption, a metric for measuring the real time entertainment value of predator/prey games was established as an efficient and reliable entertainment ('interest') metric by validation against human judgement [21].

Following the theoretical principles reported from Malone [8], Lazzarro [5], Koster [3] and Yannakakis [18], this paper is primarily focused on the game opponents' behavior contributions — by enabling appropriate learning patterns for the player to be further trained on [3] — to the real-time entertainment value of the game. We argue that among the three dimensions of "fun" (*endurability, engagement, expectations*) defined in [12] it is only engagement that is affected by the opponent since both *endurability* and *expectations* are primarily generated by the game design per se. Given a successful interactive game design that yields *expectations* and *endurability* (such as the Playware platform — see Section "Experimental Data") we focus on a quantitative analysis of the level of engagement that generates fun (entertainment). Thus, instead of being based on empirical or visual observations of children's engagement [12], the work presented here proposes a comparative fun analysis method that quantitatively extracts the correlation between Malone's entertainment factors and the human notion of entertainment measured by experimental data from a survey with children playing with the Playware playground.

Playware Playground

Children's and youth's play has seen major changes during the last two decades. New emerging playing technologies, such as computer games, have been more attractive to children than traditional play partly because of the interactivity and fantasy enhancement capabilities they offer [3]. These technologies have contributed to transforming the way children spend their leisure time: from outdoor or street play to play sitting in front of a screen [6, 14]. This sedentary style of play may have health implications [7].

A new generation of playgrounds that adopt technology met in computer games may address this issue. More specifically, intelligent interactive playgrounds with abilities of adapting the game according to each child's personal preferences provide properties that can keep children engaged in entertaining physical activity. On that basis, capturing the child's entertainment and adjusting the game in order to increase it can only have positive effects on the child's physical condition. The Playware playground adopts these primary concepts.

Playware Technology

The Playware [7] prototype playground consists of several building blocks (i.e. tangible tiles — see figure 1) that allow the game designer (i.e. the child conceptually) to develop a significant number of different games within the same platform. For instance, tiles can be placed on the floor or on the wall in different topologies to create a new game [7]. The overall technological concept of Playware is based on embodied artificial intelligence (AI) [11] and specifically a robotic building block concept [7] where intelligent physical identities (tiles) incorporate processing power, communication, input and output, focusing on the role of the morphology-intelligence interplay in developing game platforms.

Specifications

The Playware tile's dimensions are 21 cm x 21 cm x 6 cm (width, height, depth) and each incorporates a microcontroller and connection ports to support communication between the tiles. Visual interaction between the playground and children is achieved through four light emitting diodes (LEDs) which are connected to the microcontroller. In this prototype game world, users are able to interact with the tiles through a Force Sensing Resistor (FSR) sensor embedded in each tile. A rubber shell is used to cover the hardware parts of the tile and includes a "bump" indicating the location of the FSR sensor (i.e. the interaction point) and a plexiglass window for the LEDs (see figure 1).

Systems Related to Playware

The Smart Floor [10] and the KidsRoom [1] are among the few systems that are conceptually similar to the Playware tiles. The first is developed for transparent user identification and tracking based on a person's footstep force features and the latter is a perceptually-based, multi-person, fully automated, interactive, narrative play room that adjusts its behavior (story-line) by analyzing the children's behavior through computer vision. As far as the concept of intelligent floors consisting of several building blocks is concerned, the Z tiles [13] are closely related to Playware. However, the Z tiles are mainly used as input devices only whereas Playware comprises building blocks that offer interactivity by incorporating both input and output devices.

figure 1. The tiles used in the Playware Playground.

Finally, the *Scorpiodome* game system [9] is consistent with the Playware digitally augmented environment and grid/tiles concept; however, *Scorpiodome* is primarily designed for investigating social, non-physical gaming — being a platform for deploying augmented reality games with remote controlled toy vehicles — and outside the principles of embedded AI within its *Active Landscape Grid* components/tiles.

Exergaming products such as *QMotions* and Konami's *Dance Dance Revolution* series of games constitute examples of entertainment media that mix physical activity with computer game playing. However, Playware offers the concept of building block game development which provides a much higher degree of freedom and flexibility in game designing. Thus, the aforementioned games constitute a sub-class of the games that can be designed with Playware.

Bug-Smasher Game
The test-bed game used for the experiments presented here is called 'Bug-Smasher'. The game is developed on a 6 x 6 square tile topology (see figure 2). During the game, different 'bugs' (colored lights) appear on the game surface and disappear sequentially after a short period of time. A bug's position is picked within a radius of three tiles from the previous bug and according to the predefined level of the bugs' spatial diversity. Spatial diversity is measured by the entropy of the bug-visited tiles which is calculated and normalized into [0, 1] via (1).

$$H = \left[-\frac{1}{\log 36} \sum_i \frac{v_i}{V} \log\left(\frac{v_i}{V}\right) \right] \quad (1)$$

where v_i is the number of bug-visits to tile *i* and *V* is the total number of visits to all visited tiles (i.e. $V = \sum_i v_i$). If the bug visits all tiles equally then $v_i = V/36$ for all 36 tiles and *H* will be 1; if the bug visits exactly one tile, *H* is zero.

figure 2. A child playing the Bug-Smasher game.

The child's goal is to smash as many bugs as possible by stepping on the lighted tiles. Different sounds and colors represent different bugs when appearing and when smashed in order to increase the fantasy entertainment factor [8]. Moreover, feedback to the player, which is essential for a successful game design [8], is provided through different characteristic sounds that represent good or bad performance.

Experiment
The Bug-Smasher game has been used to acquire data of human judgement on entertainment. The game uses two different states ('Low' and 'High') of Malone's [8] three entertainment factors to generate a pool of 8 dissimilar games for children to play.

We consider the speed (*S*) that the bugs appear and disappear from the game and their spatial diversity (*H*) on the game's plane as appropriate measures to represent the level of challenge and the level of curiosity (unpredictability) respectively [8] during gameplay. The former provides a notion for a goal whose attainment is uncertain — the higher the *S* value, the higher the goal uncertainty and furthermore the higher the challenge — and the latter effectively portrays a notion of unpredictability in the subsequent events of the game — the higher the *H* value the higher the bug appearance unpredictability and therefore the higher the curiosity. Finally, the level of fantasy corresponds to the number of different bugs (different colors and sounds) appearing in the game.

To that end, 28 children whose age covered a range between 8 and 10 years participated in a comparative fun experiment. In this experiment, each subject plays two games (*A* and *B*) — differing in the levels of one or more entertainment factors of challenge, curiosity and fantasy — for 90 seconds each. Each time a pair of games ('game pair') is finished, the child is asked whether the first game was more interesting than the second game i.e. whether *A* or *B* generated a more interesting game. In order to minimize any potential order effects we let each subject play the aforementioned games in the inverse order too. Statistical analysis shows that the order of playing Bug-Smasher games does not affect children's judgement on entertainment [17].

For the design of the children's self reports we follow the principles of comparative fun analysis presented in [12] and [18]. The *endurability* and *expectations* levels for the majority of children that played with Playware were very high indicating that the game design used for Bug-Smasher was successful. More specifically, all children were excited to play with Playware as soon as they were informed about the rules of the game and the vast majority of children stressed that they would like to play the game again. As previously mentioned, we use the 2-alternative forced choice (2-AFC) approach since it offers several advantages for a subjective entertainment capture. The 2-AFC comparative fun analysis minimizes the assumptions about children's different notion of entertainment and provides data for a fair comparison among answers of different children.

Analysis

The aim of the statistical analysis presented here is to identify statistically significant correlations between human notion of entertainment and any of Malone's three entertainment features. For this purpose the following null hypothesis is formed: The correlation between observed human judgement of entertainment and the examined features, as far as the different games played are concerned, is a result of randomness. The test statistic is obtained through $c(\vec{z}) = 1/\mathrm{N}\sum_{i=1}^{\mathrm{N}} z_i$ where N is the total number of game pairs where the games have different levels of *S* and/or *H* and/or fantasy and $z_i = 1$, if the subject chooses as the more entertaining game the one with the larger value of the examined entertainment feature and $z_i = -1$, if the subject chooses the other game in the game pair *i*.

Table 1 presents the $c(\vec{z})$ values and their corresponding p-values for the three entertainment features. Fantasy appears to be the only feature examined that is significantly — significance equals 5%, high significance equals 1% in this paper — correlated to entertainment; recall that fantasy in this game is defined as number of different bugs (different colors and sounds) appearing in the game. The obtained effects show that fantasy is objectively contributing for a more entertaining game whereas the levels of challenge and curiosity are dependent on each child's individual requirements.

Entertainment Factor	$c(\vec{z})$	*p-value*
Challenge (*S*)	0	0.5699
Curiosity (*H*)	-0.0625	0.43005
Fantasy	0.625	0.000268

Table 1. Correlation coefficients and their corresponding p-values between entertainment and Malone's quantitative entertainment factors.

Previous work [17] on the Bug-Smasher game has shown that the mapping between challenge, curiosity and entertainment appears to follow the qualitative principles of Malone's work [8]. According to these, a game should maintain an appropriate level of challenge and curiosity in order to be entertaining. In other words, too difficult and/or too easy and/or too unpredictable and/or too predictable opponents to play against make the game uninteresting.

Conclusions

This paper projects the advantages of play on digitally-augmented interactive intelligent playgrounds and introduces a comparative fun analysis on the innovative Playware physical playground. The comparative fun analysis proposed follows the *endurability, expectations* and *engagement* principles of Read et al. [12]. However, the focus of the analysis is on the *engagement* factor of fun which is based on the qualitative principles of Malone's intrinsic factors for engaging gameplay [8]. More specifically, the quantitative impact of the factors of challenge, curiosity and fantasy on children's entertainment were investigated through the Bug-Smasher game played on the Playware playground.

Experiments show that fantasy is an objectively correlated factor to children's entertainment whereas challenge and curiosity depend on each child's individual needs from the game design. These results follow the theoretical principles of Malone and demonstrate generality over the majority of action games created with Playware and/or other augmented reality game systems. Preliminary studies have already shown that fantasy's effect to entertainment generalizes to other dissimilar Playware designed games.

The current work is limited by the number of participants in the game survey we devised. More states for the measurable metrics of challenge, curiosity and fantasy need to be obtained and investigated in a future study. The challenge that arises here is that the number of subjects required for experiments like the one reported here is factorial with respect to the number of states chosen for the entertainment factors and the total number of entertainment factors under investigation.

To summarize, an intelligent game design that maintains high levels of fantasy and adjusts challenge and curiosity according to the child's individual requirements appears to be the desired approach for augmenting the level of engagement and fun of children.

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