

O Futuro dos Jogos Distribuídos: Vantagens Técnicas e Design Centrado no Utilizador

The Future of Distributed Gaming:
Technical Advantages and User-Centred
Design

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Resumo

Há uma procura potencial por soluções multimédia interactivas em rede que permitam utilizar jogos de PC em set-top boxes, PDAs ou outros dispositivos móveis de baixo custo. O projecto Games@Large (GaL) tem desenvolvido uma solução que permitirá a acessibilidade ubíqua de meios interactivos em dispositivos com poucas capacidades tecnológicas. Este artigo descreve a estrutura do GaL e a abordagem ao ciclo de vida de engenharia de usabilidade que foi usada para iterativamente desenvolver e avaliar um protótipo funcional com um interface amigável. O primeiro estudo empírico mostra que o interface do GaL está de acordo com os standards de usabilidade para todos os grupos de utilizadores propostos e os jogos do GaL proporcionam experiências mais positivas do que os exemplares actuais. Um segundo estudo empírico é efectuado para explorar se a experiência dos jogadores no sistema GaL é acompanhada pelo atractivo dos gráficos. Os resultados revelaram que a qualidade gráfica percebida é significativamente superior que o estado-da-arte de streaming de vídeo. Estudos futuros permitirão explorar mais as vantagens e as possíveis limitações do sistema GaL numa escala mais alargada de jogos e de utilizadores.

Palavras-chave: *Gaming-on-demand, Streaming, Design Centrado no Utilizador, Estrutura Games@Large, Experiência do Jogador*

Abstract

There is a potential demand for networked interactive media solutions that enable the rendering of PC games on set-top boxes, PDAs or low-cost CE devices. The Games@Large (GaL) project has been developing such a solution that would enable pervasive accessibility of interactive media from low-end devices. This paper describes the GaL framework and the usability engineering lifecycle approach that was used to iteratively develop and evaluate a working prototype with a user-friendly interface. The first empirical study shows that the GaL interface meets usability standards for all proposed user groups and that GaL games are more positively experienced than current exemplars. A second empirical study is performed to explore if players' experience on the GaL system is accompanied by the appeal of graphics. Results revealed that the graphics quality is perceived significantly higher than state-of-the-art video streaming. Future studies will further explore the advantages and possible limitations of the GaL system with a wider range of games and users.

Keywords: *Gaming-on-demand, Streaming, User-Centred Design, Games@Large Framework, Player Experience*

1. Introduction

Digital gaming has grown into a booming business. In 2007, computer game sales have tripled to \$9.5 billion since 1996 in the USA (ESA, 2008) and reached 7.3 billion in Europe (Nielsen Interactive Entertainment, 2008). As early as 1998, Americans spent even more money on computer games than the amount they spent on cinema tickets (Dill & Dill, 1998). Nearly all western children play digital games; in the UK for instance, nearly all 6-15 year-olds, and 82% of 16-24 year-olds, play digital games (Pratchett, 2005), with similar figures in the USA (Roberts, Foehr & Ridout, 2005) and Canada (ESAC, 2008). However, digital games are also popular among other age groups; about a third of US parents play digital games too. In fact, the average game player in the USA is 35 years old and the percentage of elderly gamers (50+ years) increased from 9% in 1999 (ESA, 2005) to 26% in 2008 (ESA, 2008). Gaming could be considered one of the fastest growing means of entertainment for all age groups and digital gaming technology is changing faster than ever to suit customers' needs and to stay ahead of the competition.

One of the latest advancements in gaming technology is games-on-demand (GoD) by means of cloud computing. Interest in such gaming-on-demand services, which enable users to stream or download full-featured electronic games to their personal computer (PC) or game console via the Internet, is strongest among game enthusiasts but has potential mass appeal. A recent survey (Cai, 2004) indicated that more than 50 percent of online game enthusiast households are interested in such a service from their broadband carriers. Aligned with such findings, telecom operators in general, and internet service providers (ISPs) in particular, already include online gaming over the broadband network as an important service feature of their video entertainment bundles. But the patterns of entertainment services and video game consumption are changing. Mobility and digital home entertainment appliances have generated the desire to play games not only in front of a home PC but everywhere inside the house and on the move. Several low-cost consumer electronics end-devices are already available at home: as a result of TV digitalization, set-top boxes (STBs) have entered the home and, as a new trend, mini-laptops are gaining popularity. Although these devices are capable of executing software, modern 3D computer games are too heavy for them (Jurgelionis et al., 2009). Running interactive content-rich multimedia applications such as video games requires high performance PC hardware or a dedicated gaming console (Nave et al., 2008).

There is a potential demand for networked interactive media solutions that enable the rendering of PC video games on set-top boxes, PDAs or low-cost consumer electronic devices without a significant price increase. The Games@Large (GaL) project (www.gamesatlarge.eu) has been developing such a solution that would enable pervasive accessibility of interactive media through low-end devices that rely on different platforms (architectures and operating systems), thus facilitating users to enjoy video games in various environments (e.g., home, hotel, internet café, elderly home) without the need to use high-end devices, such as consoles or PCs. A key aspect of this solution is streaming the output of computer games within a local area network from a central server to an end device. Depending on the capabilities of the end device, different streaming techniques may be used. The GaL project has investigated two different approaches to streaming: (i) video streaming of already rendered frames of the game and (ii) streaming of graphics commands for local rendering on the end device i.e. 3D graphics streaming (Eisert & Fechteler, 2007).

1.1. Overview of current gaming-on-demand systems

User uptake of gaming platforms and choice of console depend not just on hardware specifications and functionality but also games catalogues and online services. PC games are effectively tied to the desktop/laptop and console gaming is seen by many as expensive or for dedicated gamers only. The Nintendo Wii has broadened the console user base but there remains a massive potential for mainstream gaming on TV given the right technology solution, content and services offerings and pricing. There are several established or forthcoming games-on-demand and games streaming solutions incorporating one or more of the following elements: downloading and execution of the game on local devices; streaming within a local network; streaming from remote servers. Advances in wireless home entertainment networks and connectivity – which stream content between devices within the home – present potential solutions for playing PC games on TV. Airgo Networks' faster-than-wired True MIMO Media technology and Orb MyCasting are notable but do not allow streaming of games. *StreamMyGame* (Tenomichi Limited) streams any DirectX PC game running on a main PC to a wide range of lower-end devices in the home including PCs, notebooks, netbooks, UMPCs, other Linux devices and the PlayStation 3 (players use the Sixaxis Controller as usual). Users can also record their game play or broadcast games for spectators. *StreamMyGame* also enables games to be played remotely over broadband (and wireless, mobile and WiMAX) networks that have sufficient capacity, potentially supporting Pay-for-Play services to existing PCs, PS3s and STBs.

Streaming video or graphics from remote servers to the PC or to the TV is the most common approach for games-on-demand. Examples of these services are: *Zeebo*, a Wireless 3G video game console based on low-cost hardware and BREW platform solutions which is targeting the huge developing markets of Brazil, Russia, India and China (BRIC); with the *EXEtdender™* technology (Exent Technologies Ltd.) and *AWOMO* (Virgin Games), games are downloaded over broadband and executed locally on a PC – however, the user can start playing the game after just a small initial download with remaining data being continuously fetched during game play; *InstantAction* (GarageGames) uses a small plug-in and an initial download of the game to allow users to play 3D games in their web browser; *Xtremeplay* (NDS) enables high resolution streaming of computer games to set-top boxes; *t5 labs*' 'Instant Gaming' solution for set-top boxes via centralized servers hosted by cable TV or IPTV operators; *OTOY/AMD*'s Fusion Rendering platform offers film-quality graphics games to any internet-enabled device – computer, set-top box or even iPhone; *G-Cluster* also offers compression of game content and its streaming as MPEG over the IP network to the IP-STB.; finally, broadband games-on-demand service *OnLive* will use video streaming and compression technologies for gaming on PC or Mac without downloads and their 'micro-console' device will also allow gaming on TV.

1.2. Games@Large Framework

The GaL framework (Tzruya, Shani, Bellotti, and Jurgelionis, 2006) consists of several components. First, a Windows PC Local Processing Server (LPS) runs games from the Local Storage Server (LSS) and streams them to clients. It is responsible for launching the game process after client-side invocation, managing its performance, allocating computing resources, filing system and I/O activities, and capturing the game graphics commands or already rendered frame buffer for video encoding, as well as managing execution of multiple games and streaming audio. The LPS is further responsible for receiving the game controller commands from the end device and injecting them into the game process.

Second, the graphics streaming protocol is used for streaming 3D commands to end devices allowing lower performance devices such as interactive TV set-top boxes (STBs) to present high performance 3D applications such as games without the need to actually execute the games locally. The 3D streaming and remote rendering system developed for GaL are achieved through an architecture based on multiple encoding and transmission layers (Jurgelionis et al., 2009). The first layer is the graphics' commands interception on the server and the last one is the rendering on the client. All the intermediate layers are independent of

any specific graphics Application Program Interface (API). This implies that the 3D streamed data are not specific to either DirectX or OpenGL but abstract higher-level concepts common to all 3D graphics (Jurgelionis et al., 2009). The 3D graphic streaming approach cannot be used for several mobile devices that lack the hardware capability for accelerated rendering and cannot render the images locally for displaying. For such cases, the Video streaming scenario is applied, exploiting H.264 (ISO, 2003) for low-delay video encoding.

Third, the network connection to the game client can be either wired or wireless. GaL wireless platform relies on the IEEE 802.11 standard family (IEEE, 1999). Currently, the mostly used WLAN technology is IEEE 802.11g that can, in good conditions, provide the bandwidth needed for four simultaneous game sessions (Jurgelionis et al., 2009). Priority-based QoS can be supported in IEEE WLANs with the Wi-Fi Multimedia (WMM) extensions (Jurgelionis et al., 2009), (Wi-Fi Alliance Technical Committee, 2004) specified by the Wi-Fi Alliance.

Additionally, the client module, running on a Windows/Linux PC or notebook or WinCE/Linux STB or a Linux-based handheld, receives the 3D graphics command stream and does the local rendering using the available capabilities (OpenGL or DirectX). For the video streaming approach, H.264 decoding must be supported, instead. The client is also responsible for capturing the controller (e.g. keyboard or gamepad) commands and transmitting them to the processing server (Nave et al., 2008).

1.3. Technical advantages and challenges

The state-of-the-art gaming-on-demand systems offer a variety of possibilities, but are still unable to support high-level interactive media such as current successful game titles. Such applications now need costly ad-hoc adaptation and down-sizing. Using them seamlessly on a variety of devices would dramatically enlarge the market and increase the user options and experiences (e.g., allowing multi-player gaming in various environments such as homes, hotels, internet cafés, elderly houses).

The GaL approach enables the pervasive accessibility of interactive media from devices that feature different platforms (hardware and operating systems), thus facilitating users to enjoy video games in various distributed environments without the need for using a single device or operating system (Jurgelionis et al., 2009). Moreover, using a single PC to execute multiple games and stream them with a high visual quality to concurrently connected clients via a wireless or wired network supporting Quality of Service (QoS) (Jurgelionis et al., 2009) facilitates the creation of scalable systems for larger deployments. The GaL technology allows

doing distributed, high-quality PC gaming on network-connected TVs, which is a rapidly emerging requirement in the game market.

2. User-centred design and evaluation

Important goals of the GaL project are creating a platform on which computer games can be played, providing easy access to games, enabling personalization options and offering controllability of displayed content, for a wide range of users. Although GaL should be able to stream to low-end devices, all targets have to be met without negatively influencing the player experience (by offering state-of-the-art games) and the game's image quality (by the use of 3D streaming). To accomplish this, it is important to gather an in-depth understanding about the needs and abilities of all potential users. *User centred design* methodology (Norman, 1986) stresses to do so at an early stage of engineering processes, when design adaptations are still relatively easy to make. Nielsen (1993) introduced the 'usability engineering lifecycle model', consisting of iterative cycles of (re)evaluation and (re)designing focussed on users. The model indicates competitive analysis (benchmarking) as an important method to evaluate whether a system's design follows current conventions and meets quality standards that users expect from contemporary systems. Adopting the usability engineering lifecycle approach, a first working GaL prototype was developed and subsequently evaluated with actual users. Furthermore, to comprehensively understand the effects on users; the usability engineering lifecycle approach was extended by adding player experience to the model.

In the initial stage of the cycle, a considerable number of user-centred studies have been performed within the GaL project. User needs and characteristics of all proposed user groups and play environments were gathered (e.g., Gajadhar, de Kort & IJsselsteijn, 2009; Nap, de Kort & IJsselsteijn, 2009a). Findings were subsequently used during prototyping by means of personas and contextual scenarios. A low-fidelity paper prototype then allowed for an early validation of the interaction design by using expert cognitive walkthroughs, followed by a second evaluative iteration to filter usability flaws that have not yet surfaced. Therefore, six heuristic categories – consistency, simplicity, feedback, control, error, and cognitive-overload – were extracted from literature (Coats & Vlaeminke, 1987; Nielsen & Molich, 1990; Nielsen, 2008; Shneiderman, 1998) and used by five usability experts for evaluating the mid-fidelity prototype. The usability problems found were resolved in a high-fidelity prototype; a second heuristic evaluation showed a considerable reduction (by 50%) in the usability flaws (see, Nap, Gajadhar, Oosting, de Kort & IJsselsteijn, 2009b).

In addition to user centred interface prerequisites, network game systems require Quality of Service standards that should be met (Jehaes et al., 2003). Therefore, standard HCI methods (e.g. Henderson, 2001) were applied to measure the effects of the GaL system's network performance – latency, jitter, packet loss – on users. Additionally, digital gaming is a leisure activity which is primarily performed to have a good experience in terms of fun, relaxation and social interaction (Nielsen, 2008; Gajadhar, de Kort, IJsselsteijn & Poels, 2009). Therefore player experience was included as a possible indicator for effects of network impairments (in line with Gajadhar, Nap, de Kort, IJsselsteijn & Oosting, in preparation). Player experience was addressed by applying the Game Experience Questionnaire (GEQ), which has been developed by Poels, de Kort and IJsselsteijn (2008). Empirical findings (see Nap & colleagues, 2009b) of the network performance tests were subsequently used to improve the GaL prototype, in order to meet the state-of-the-art user requirements regarding system performance on games-on-demand systems.

By means of the usability engineering lifecycle the high-fidelity prototype needed testing with actual users. Nielsen (1993) describes this phase as *Usability Testing*, in which end-users perform realistic tasks on the interface of which the results provide knowledge about the 'ease of use' of the system under study. Therefore, user tests were performed to gather an extensive insight in the user friendliness of the GaL UI for different potential user groups. Furthermore, the GEQ was again employed to study users' experiences. Since Poels et al. (2008) validated the GEQ on several user groups ($N = 380$) that played their games in varieties of play environments on the most popular platforms, their data can be used as a benchmark to compare the user evaluations of the GaL system with. After all, the GaL project aims at providing at least a similar player experience as current conventional gaming systems on the market. Furthermore, GaL's graphics quality was benchmarked with a state-of-the-art video streaming system.

Study 1

Method

Participants, Apparatus & Procedure: Seventeen families and two groups of young adults ($N = 68$; all Portuguese) were invited for participation in the user experiment, designed by Eindhoven University of Technology and PTIN, and performed at a usability lab in Aveiro, Portugal (see Figure 1 for an overview of the setting). Thirteen children ($M_{Age} = 8.7$; $SD_{Age} = 1.3$; 5 female), twelve adolescents ($M_{Age} = 13.6$, $SD_{Age} = 1.4$; 6 female), nine young adults

($M_{Age} = 21.0$, $SD_{Age} = 2.3$; 2 female), and thirty-four parents ($M_{Age} = 38.1$, $SD_{Age} = 6.5$; 16 female) participated. All participants had experience with computers and the Internet; four parents did not have experience with digital gaming. The participants performed a set of representative tasks on the GaL UI and furthermore played a number of games (see, Nap et al., 2009b). The order of the game tasks and UI tasks was counterbalanced. Two games were used: a fast paced puzzle game *Sprill*, and a slow paced puzzle game *Mahjong*. After the sessions, they were debriefed, received an USB memory stick for their time in the study, and were thanked for participation. The usability study took about 1 hour and 30 minutes.



Figure 1: Participants (children) playing games on the GaL system

Measures: Usability was operationalized according to the ISO 9241-11 usability norm (ISO 9241-11, 1998) and measured by the number of tasks performed correctly (effectiveness), total task time (efficiency), and satisfaction by means of the IBM Usability Questionnaire (IBM-UQ; Lewis, 1995). After each UI task, participants completed a set of self-report measures in which they rated the perceived usability of the GaL UI. The reliability for each IBM-UQ scale – SYSUSE, INFOQUAL, and INTERQUAL – represented by Cronbach’s alpha ranged between .83 and .96 for each task.

Player experience was measured by using seven scales from the core version of the GEQ (Poels et al., 2008), which can be appropriately administered to adolescents, young adults and parents. The GEQ was filled in after the game task. Children did not fill in the IBM-UQ and the GEQ, since in general, questionnaires should rather be avoided in the evaluation of products with children below the age of 10 (see, Markopoulos et al., 2008). Reliability on each GEQ scale is given in Table 1 for *Sprill*, *Mahjong*, and the data for Benchmark Puzzle collected by Poels et al. (2008).

Table 1. Schematic overview of the internal consistency on each scale of the GEQ for Sprill, Mahjong and Benchmark Puzzle.

	Pos.Affec	Competen	Challeng	Frustratio	Flo	Boredo	Immersio
Sprill	.95	.94	.47	.91	.91	.57	.88
Mahjong	.90	.91	.39	.91	.90	.40	.87
Benchmar	.80	.83	.75	.81	.87	.71	.89

Results/Discussion

Usability: Linear Mixed Model Analysis (repeated measures) was performed on task effectiveness, task efficiency, and self-reports with Age Group and UI-Task as fixed factors and subjects as random factor; Internet Experience was included as a covariate.

No significant effects of Internet Experience on Task Effectiveness, nor were significant differences on effectiveness between age groups found (see Figure 2a), hence the UI is highly accessible for the whole family. Moreover, most participants were able to perform the tasks correctly within the time limit ($M_{Task1} = .97 (.17)^1$; $M_{Task2} = .90 (.03)$).

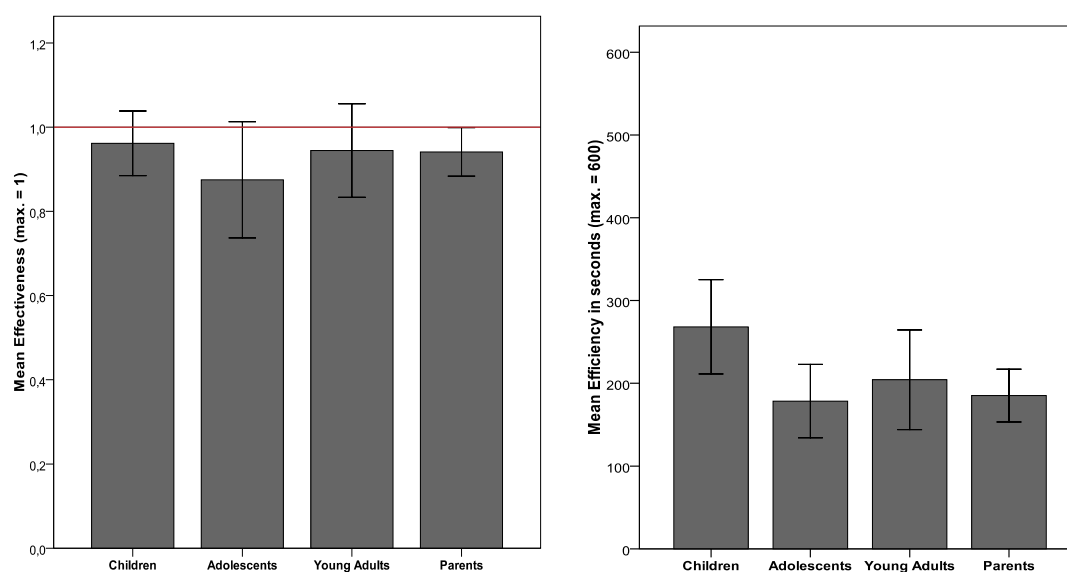


Figure 2: a) Overview of the mean effectiveness scores per age group (SE indicated in graph); b) Overview of the mean efficiency scores per age group (SE indicated in graph).

¹ Standard errors between brackets

About all participants were able to perform the search tasks far within the time limit of 600 seconds (see Figure 2b). The mean time in seconds for Task 1 was 176.5 (102.9) and for Task 2 it was 229.7 (149.9). No significant effects were found of Internet Experience on the usability satisfaction components. All age groups were satisfied with the UI, above scale midpoint (see Figure 3). Interestingly, overall usability satisfaction was significantly higher rated by adolescents ($M = 6.0 (.7)$) than by parents ($M = 4.9 (1.4)$).

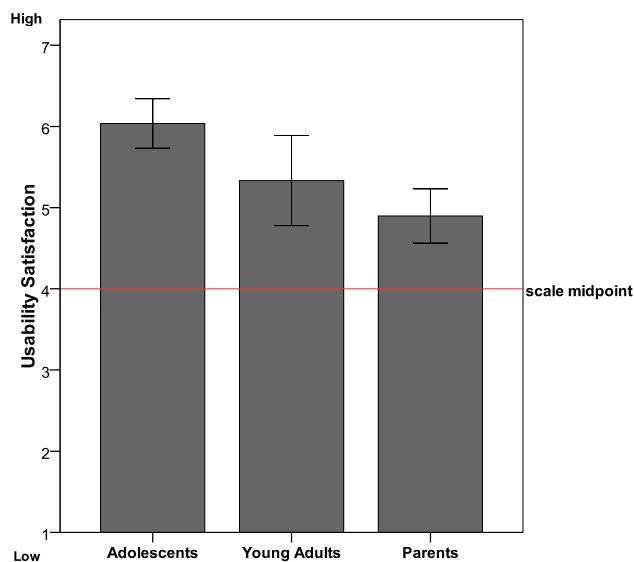


Figure 3: Overview of the mean usability satisfaction scores per age group (1 = low satisfaction; 7 = high satisfaction; SE indicated in graph; scale midpoint = 4)

Player experience: Two separate MANOVAs were performed for the comparisons of Sprill and Mahjong with the Benchmark Puzzle games. Results revealed that for Sprill and Mahjong significant differences were measured in positive affect, challenge, frustration, boredom, immersion, flow (see Table 2). No significant differences were found for competence.

Table 2. Schematic overview of the significant differences and effect sizes for the GEQ scale between Sprill and the Benchmark Puzzle and between Mahjong and the Benchmark Puzzle.

		Sprill	Mahjong	Benchmark Puzzle
Pos.Affect	<i>M</i>	3.6**	3.9**	3.1
	<i>SD</i>	0.9	0.7	0.8
	<i>R</i> ²	.09	.21	
Challenge	<i>M</i>	2.1(*)	2.0*	2.3
	<i>SD</i>	0.5	0.5	0.8
	<i>R</i> ²	.03	.05	
Frustration	<i>M</i>	1.2**	1.2**	1.7
	<i>SD</i>	0.4	0.4	0.7
	<i>R</i> ²	.16	.20	
Flow	<i>M</i>	3.3**	3.5**	2.2
	<i>SD</i>	1.0	0.9	1.1
	<i>R</i> ²	.21	.30	
Boredom	<i>M</i>	1.4**	1.3**	2.0
	<i>SD</i>	0.5	0.4	0.7
	<i>R</i> ²	.19	.30	
Immersion	<i>M</i>	3.0**	3.0**	1.7
	<i>SD</i>	1.7	0.9	0.7
	<i>R</i> ²	.37	.41	

** < 0.01; * <0.05; (*) = marg. sign.; *M* = Mean; *SD* = Standard Deviation; *R*² =

Regarding the effect sizes, differences on player experience scales that relate to involvement (see Figure 4b) between Sprill/Mahjong and the Benchmark Puzzle are larger than differences in enjoyment related scales (see Figure 4a). The largest difference was found on immersion, which reflects the attractiveness of the game by audio and graphics or storyline.

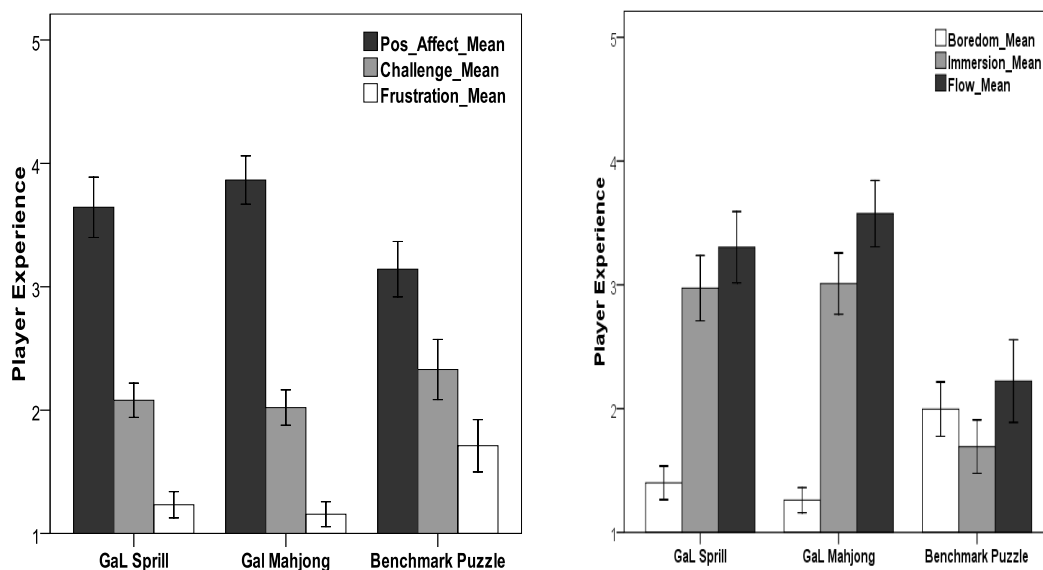


Figure 4: a) Enjoyment related GEQ scales scores for Sprill, Mahjong and Benchmark Puzzle (1 = not at all; 5 = extremely; SE indicated in graph); b) Involvement related GEQ scales scores for Sprill, Mahjong and Benchmark Puzzle (1 = not at all; 5 = extremely; SE indicated in graph).

The user studies revealed that the GaL UI is usable for a wide range of users. Children, adolescents, young adults, and parents were able to interact with the UI, effectively, efficiently, and satisfactorily. Interestingly, adolescents – who are in general highly experienced gamers on multiple platforms – were more satisfied with the UI than parents, which indicates competitiveness of GaL’s UI. In addition, games played on the GaL system are experienced more positively than on current exemplars. In particular users experienced higher immersion, which reflects the attractiveness of the game by audio and graphics or storyline. Since GaL allows for high graphics quality by 3D streaming, a second study was performed to explore if GaL’s player experience is accompanied by an increase in the appeal of graphics. GaL’s 3D streaming was empirically compared to a state-of-the-art video streaming service; ‘StreamMyGame’ (SMG).

Study 2

Method

Experimental Design & Procedure: A (2x3) fully counterbalanced mixed groups design was employed, with System (SMG vs. GaL) as the between subjects factor and Game as the within subjects factor. All participants played four sets of two randomly chosen games on one of the systems, and after each session they were asked to complete a self-report on the player

experience. Each of the eight sessions took approximately 10 minutes, which included play time (5 min.), filling in the questionnaire (3 min.), and rest (2 min.). Eight play sessions were repeated on the following day changing the order of games. Afterwards they were debriefed, paid and thanked for participation. In total, participation over the two days lasted 3 hours and participants received a compensation of €30.

Participants & Apparatus: Sixty-three Dutch undergraduate and postgraduate students ($M_{Age} = 21.1$; $SD_{Age} = 2.3$; 15 female) participated in the experiment. Three different games were used from different game genres, namely two puzzle games *Sprill* and *Mahjong*, and a Third Person Shooter *Total Overdose*², which were played (single player) on a 15.4" laptop.

Measures: A Mean Opinion Score (MOS) scale measured the appeal of graphics using the item “the graphics in the game were acceptable”.

Results

Linear Mixed Model Analysis (repeated measures) was performed on self-reports with System and Game as fixed factors, and subjects as random factor to allow inferences of a wider population. Figure 5 presents the mean graphics ratings for each of the games on the two systems.

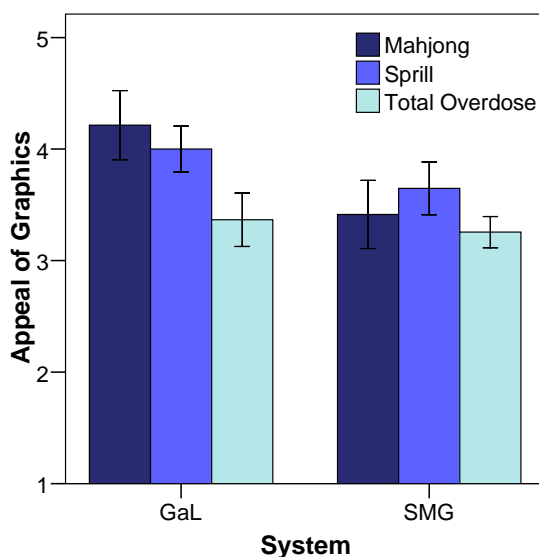


Figure 5: Mean appeal of graphics for each Game as a function of System (1 = not at all; 5 = extremely; SE indicated in graph).

² Total Overdose was not included in the first study because the violent content was not suitable for especially the young family members.

Results showed a significant main effect for System ($F(1,94.5) = 7.78$; $p < .01$). The graphical quality of the GaL system was perceived significantly higher than the SMG system ($M_{\text{GaL}} = 3.8$ (0.1); $M_{\text{SMG}} = 3.4$ (0.1)). Furthermore, the analysis revealed a significant main effect for Game ($F(2,216.7) = 20.18$; $p < .001$). Contrast analyses showed a significant difference between Total Overdose and Sprill with Mahjong (both; $p < .001$). Participants scored the graphical quality of both games Mahjong ($M = 3.8$ (0.1)) and Sprill ($M = 3.8$ (0.1)) as significantly higher than for Total Overdose ($M = 3.3$ (0.1)). Additionally, an interaction effect was found for Game with System ($F(2,217.7) = 5.06$; $p < .01$). Further analysis (the same analysis, however per game) revealed that Mahjong was responsible for the significant main effect of System on perceived graphical quality ($F(1,27.7) = 8.72$; $p < .01$).

3. General discussion

Laboratory experiments have shown that the GaL system is capable of running video games of different genres, also including First Person Shooter games that are very popular and usually highly interactive and demanding for high end device performance. A GaL server can be hosted on a single PC and support multiple game executions and streaming with a high visual quality to concurrently connected clients via a wireless / wired network, in particular exploiting a QoS solution, which improves systems performance also in the presence of competing traffic (Jurgelionis et al., 2009). Furthermore, our technical performance tests of the GaL system showed that the quality of a gaming experience is typically correlated with the game frame rate, bandwidth, resolution, and controller capabilities (e.g., some games cannot be controlled with a gamepad or a PDA keypad).

The usability engineering lifecycle approach (Nielsen, 1993) was employed to iteratively design and evaluate a working GaL prototype. The prototype was studied in two user experiments: the first with a focus on the usability of the UI and the player experience on the system in comparison with a benchmark, and a second comparing perceived image quality of GaL to state-of-the-art video streaming. The first user study showed that the UI of GaL is usable for the whole family. All age groups were able to perform realistic tasks effectively with high efficiency and were satisfied with the ease-of-use of the UI. Results on player experience revealed that GaL was more enjoying and engaging than current exemplars; the immersive power of GaL surfaced. Hence, the subsequent in-depth study on image quality emphasizes the higher appeal of graphics of the GaL 3D streaming protocol compared to state-of-the-art video streaming. Findings reveal that graphics are perceived as more

appealing when induced by GaL than by SMG, especially for the puzzle game Mahjong. Both puzzle games showed the same trend; however for the FPS game no difference was found. These findings may be explained by the functional role of colours to discriminate objects in both puzzle games, which was not present in Total Overdose. Future studies will further explore the advantages and possible limitations of the GaL system with a wide range of users and game types. What we learn from these studies will be used as input for the enhancement of the system, to be evaluated again with users and experts alike.

3.1. Conclusion

From the perspective of user centred design, this article emphasizes the critical role of player experience in determining user's satisfaction with a system. By combining the usability engineering lifecycle approach with measurements on users' feelings, a complete overview is given of the GaL system in regard to other systems that are available on the market. Findings reveal that goals of the project were met, as providing a functional and usable system, for a wide range of users, with multiple customization and control possibilities without negatively influencing the player experience and the perceived image quality of the system.

From the perspective of Service Providers, the achieved solution is already aligned with the need facing Telcos for bundle innovative offers of Services & Applications that could contribute to boost customer lifetime value and profitability. However it is the ubiquity of high speed broadband and the promise to move the capability of streaming videos games directly to the Internet that seems to open new and demanding business models that will foster the Games-on-demand market.

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References

- Cai, Y.M. (2004). Entertainment on Demand: Online Gaming Services. Parks Associates.
- Coats, R. B., & Vlaeminke, I. (1987). *Man-computer interfaces: an introduction to software design and implementation*. Cambridge, MA: Blackwell Scientific Publications, Inc.
- Dill, K.E. & Dill, J.C. (1998). Video game violence: A review of the empirical literature. *Aggression and Violent Behavior, 3*, 407-428.
- Eisert, P., & Fechteler, P. (2007). Remote Rendering of Computer Games. *Proceedings of the International Conference On Signal Processing and Multimedia Applications, SIGMAP*, July 2007, Barcelona, Spain
- ESAC (2008). 'Essential facts about the Canadian computer and videogame industry'. Entertainment Software Association Canada report.
- ESA (2005). *Essential Facts About the Computer and Video Game Industry; 2004 Sales, Demographics, and Usage data*. Entertainment Software Association report.
- ESA (2008). *Essential Facts About the Computer and Video Game Industry; 2008 Sales, Demographics, and Usage data*. Entertainment Software Association report.
- Gajadhar, B.J., de Kort, Y. A.W., & IJsselsteijn, W.A. (2009). Rules of Engagement: Influence of Co-Player Presence on Player Involvement in Digital Games. *International Journal of Gaming and Computer-Mediated Simulations, 1* (3), 14-27.
- Gajadhar, B.J., de Kort, Y.A.W., IJsselsteijn, W.A., & Poels, K. (2009). Where Everybody knows your Game: the Appeal and Function of Game Cafés in Western Europe. *Proceedings of ACE 2009*, 29-31 October Athens, Greece. New York, NY: ACM, 28-35.
- Gajadhar, B.J., Nap, H.H., de Kort, Y. A.W., IJsselsteijn, W.A., & Oosting, W. (in preperation). The Curious Case of pressing a Button: an enhanced Method to study Effects of Network Performance in Digital Gaming.
- Henderson, T. (2001). Latency and User behaviour on a Multiplayer Game Server. In: J. Crowcroft and M. Hofmann, eds. *LNCS 2233*. New York, NY: Springer, 1-13.
- IEEE (1999). Std 802.11-1999 Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

- IJsselsteijn, W.A., Nap, H.H., de Kort, Y.A.W., & Poels, K. (2007). Digital Game Design for Elderly Users. *Proceedings of Futureplay 2007*, November, Toronto, Canada, (pp. 17-22)
- ISO 9241-11 (1998). Ergonomic requirements for office work with visual display terminals (VDTs) Part 11: Guidance on usability. Geneva: International Organization for Standardization.
- ISO (2003). MPEG-4 AVC - Advanced video coding for generic audiovisual services. ITU-T Rec. H.264 and ISO/IEC 14496-10 AVC.
- Jehaes, T., Vleeschauwer de, D., Coppens, T., Doorselaer van, B., Deckers, E., Naudts, W., Spruyt, K., & Smets, R. (2003). Access network delay in networked games. *ACM NetGames'03*, Redwood City, CA, 63-71.
- Jurgelionis, A., Fechteler, P., Eisert, P., Bellotti, F., David, H., Laulajainen, J.P., Carmichael, R., Pouloupoulos, V., Laikari, A., Perälä, P., De Gloria, A., & Bouras, C. (2009). Platform for Distributed 3D Gaming. *International Journal of Computer Games Technology*, vol. 2009, Article ID 231863, 15 pages. doi:10.1155/2009/231863
- Lewis, J.R. (1995). IBM Computer Usability Satisfaction Questionnaires: Psychometric Evaluation and Instructions for Use. *International Journal of Human-Computer Interaction*, 7, 57-78.
- Markopoulos, P., Read, J.C., MacFarlane, S., & Höysniemi, J. (2008). *Evaluating Children's Interactive Products – Principles and Practices for Interaction Designers*. Burlington, MA: Morgan Kaufmann.
- Nap, H.H., de Kort, Y.A.W., & IJsselsteijn, W.A. (2009a). Senior Gamers: Preferences, Motivations and Needs. *Gerontechnology*, 8(4), 247-262.
- Nap, H.H., Gajadhar, B.J., Oosting, W., de Kort, Y.A.W., & IJsselsteijn, W.A. (2009b). *User-Centred Research*. In Y. Korobkin, H. David, H.H. Nap, B.J. Gajadhar, W. Oosting, Y.A.W. de Kort, & W.A. IJsselsteijn (2009). *Alpha Model Evaluation Report*. E.U. deliverable D5B, Games@Large.
- Nave, I., David, H., Shani, A., Laikari, A., Eisert, P., & Fechteler, P. (2008). Games@Large graphics streaming architecture, *ISCE 2008*, Algarve, Portugal.

- Nielsen Interactive Entertainment (2008). *Video gamers in Europe*. International Software Federation Europe report.
- Nielsen, J. (1993). *Usability Engineering*. San Diego, CA: Academic Press.
- Nielsen, J. (2008). *Ten Usability Heuristics*. Retrieved 20 November, 2008, from: http://www.useit.com/papers/heuristic/heuristic_list.html
- Nielsen, J., & Molich, R. (1990). Heuristic evaluation of user interfaces. *Proc. ACM CHI'90 Conference*, Seattle, WA, 1-5 April, 249-256.
- Norman, D.A., & Draper, S.W. (1986). *User-Centered System Design: New Perspectives on Human-Computer Interaction*. Hillsdale, NJ: Lawrence Earlbaum Associates.
- Poels, K., de Kort, Y. A.W., & IJsselsteijn, W. A. (2008). *Game Experience Questionnaire*. E.U. deliverable D3.3, FUGA.
- Pratchett, R. (2005). *Gamers in the UK – Digital play digital lifestyles*. BBC report.
- Roberts, D.F., Foehr, U. G., & Rideout, V. (2005). *Generation M: Media in the Lives of 8–18 Year-Olds*. Kaiser Family Foundation report.
- Shneiderman, B. (1998). *Designing the user interface: Strategies for effective human-computer interaction (3rd ed.)*. Reading, MA: Addison-Wesley Publishing.
- Tzuya, Y., Shani, A., Bellotti, F., Jurgelionis, A. (2006, December). Games@Large - a new platform for ubiquitous gaming and multimedia. *Proceedings of BBEurope*, Geneva, Switzerland.
- Wi-Fi Alliance Technical Committee (2004). QoS Task Group, WMM (including WMM power save) specification V1.1.