Gaming Media and Social Effects

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Subconscious Learning via Games and Social Media

Springer

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ISSN 2197-9685 ISSN 2197-9693 (electronic)
Gaming Media and Social Effects
ISBN 978-981-287-407-8 ISBN 978-981-287-408-5 (eBook)
DOI 10.1007/978-981-287-408-5

Library of Congress Control Number: 2015933833

Springer Singapore Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer Science+Business Media Singapore Pte Ltd. is part of Springer Science+Business Media (www.springer.com)

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Introduction

The second Serious Games & Social Connect conference was held during 26–28 August 2013 in Singapore. The Serious Games & Social Connect 2013 Conference was jointly organised by the Asian Federation for Serious Games and the Serious Games Association. This annual event is used as an international platform for games developers, apps developers, government agencies staff, academics, engineers, etc. The conference is important for individuals using game mechanics in their day-to-day work as well. This book includes 11 best papers presented at the conference and related to the theme “Subconscious Learning via Games and Social Media”.

We learn best when we play. In recent years, enterprises have realised the potential of using games to introduce concepts and ideas about their services and products, the importance of using games in learning and teaching and using games as a social media platform. This was aided by the proliferation of mobile devices as well. Games are no longer played only by “digital natives”, generation which was born into the world with the Internet and mobile phones. Working adults and seniors are beginning to benefit from playing so-called serious games. Such games can be just a simple Bingo game for senior citizens to train their concentration abilities or games using the advanced immersive technologies like games for training military operators, surgeons, etc.

Recently, new types of sensors such as Electroencephalogram (EEG) devices became available for game development. This makes it possible to adapt games using brain states recognition, for example, emotion recognition from EEG. Emotion recognition algorithms can be integrated in the learning game interfaces to make learning more enjoyable process. Currently, EEG devices are widely used in neurofeedback games, for example, for the treatment of attention deficit hyperactivity disorder in children. Here, there are a lot of opportunities for game developers as the neurofeedback games have no side effects compared with traditional medical treatments. Recent study has shown that neurofeedback games help healthy children to improve their learning skills in maths and art classes.

Academic research in gaming technologies has recently witnessed a great improvement in rendering, texture mapping, physics and artificial intelligence technologies. Are there still areas where game technologies require more research? There is currently a change in focus towards the human users—user experiences, effective game story boarding, human–computer interaction and optimal experience design. With recent trends towards games for re-learning and consumer education in industries such as banking, governments and healthcare, there is indeed a lot of potential to be discussed and tapped upon.

The book puts together the papers describing all aspects of modern serious games development from situational games for occupational safety to the future of immersive technologies in serious games. We express a great thank you to the contributing authors, reviewers and editors of this book and are looking forward for a long fruitful collaboration in serious game research and development. We think this book will be an excellent contribution to research in this exciting field of serious games, and finally, everybody will benefit from the research ideas described and the games developed today and tomorrow.

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A Evaluation of 3D Character Reflectance and Realistic Implementation for FPS Game

Seongdong Kim, Seongah Chin, Jaemoon Lee and Teresa Cho

Abstract In this paper, we presented and simulated to express the realistic character simulations and our implementation for 3D game character rendering technology using Unity 3D game engine-based BRDF (bidirectional reflection distribution function). Recently some game characters for games have been almost like realistic games because of a great mathematical computation of using GPU. We introduce and implement complex 3D character rendering technique to simulate mathematical BRDF reflections from recent research to use the 3D game engine from modeling environmental lighting. This paper will be provided a real FPS (first-person shooter) game for understanding and implementing many reflectance-based lighting techniques.

Keywords BRDF · Character reflection · Diffuse model · Specular model · BSSRDF

1 Introduction

The realistic rendering image technology is of vital importance, in which the optical characteristics of the objects are considered in order for players to continue being interested and engrossed in games. To render accurate images reliably and easily, the reflectance of surfaces must be simulated accurately. The most direct way to ensure correct simulation is to use physical reflectance measurements.

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O. Sourina et al. (eds.), *Subconscious Learning via Games and Social Media*,
Gaming Media and Social Effects, DOI 10.1007/978-981-287-408-5_1

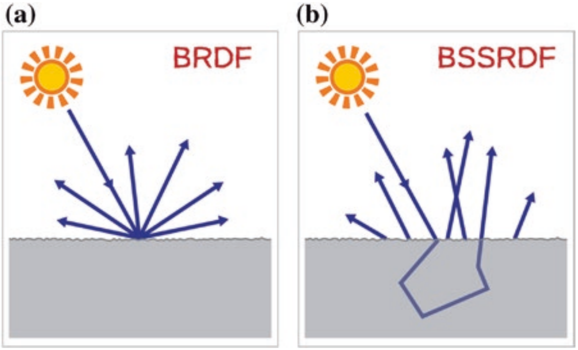

Fig. 1 Scattering phenomenon of light in **a** BRDF and **b** BSSRDF (http://en.wikipedia.org/wiki/Bidirectional_scattering_distribution_function. Accessed January 25, 2013.)

Such measurements can guide the choice of parameters for existing reflectance models, and if they are sufficiently complete, they can be used as input for renderers or provide the basis for entirely new models. To completely capture the reflectance of an opaque surface, one must measure the bidirectional reflectance distribution function (Marschner 1998). To apply the technology of a bidirectional reflection distribution function (BRDF) and how BRDFs can be used to improve realistic scene in game graphics, we begin by discussing what we know about light and how light interacts with the matter. When light interacts with matter, a complicated light–matter dynamic occurs. This interaction depends on the physical characteristics of the light as well as the physical composition and characteristics of the matter. For example, a rough opaque surface such as sandpaper will reflect light differently than a smooth reflective surface such as a mirror. Figure 1 shows a typical light–matter interaction scenario.

This paper proposes a simple and realistic BRDF model for 3D game character expression-based game engine. The model is the interaction of light with matter and is an important property for shading as indicated by Matusik of MIT (2005). The BRDF model assumes that light entering a material leaves the material at the same position as Fig. 1. Generally, when light interacts with matter, a complicated light–matter dynamic occurs. Quite much research has focused on developing models for the more general, BRDF model. A surface’s BRDF specifies how much of the light incident from any one direction is emitted in any second direction. BRDF model, originally introduced by Nicodemus et al. (1977), assumes that light striking at surface location is reflected at the same surface location as Fig. 1a. BRDFs can be simple, such as Lambertian model that causes a constant BRDF or complex, such as Cook–Torrence model. Assuming the light to exit at the same location as it entered works well for most materials, but not for translucent materials as Fig. 2 (Moon et al. 2013).[1]

[1] http://en.wikipedia.org/wiki/Bidirectional_scattering_distribution_function. Accessed January 25, 2013.

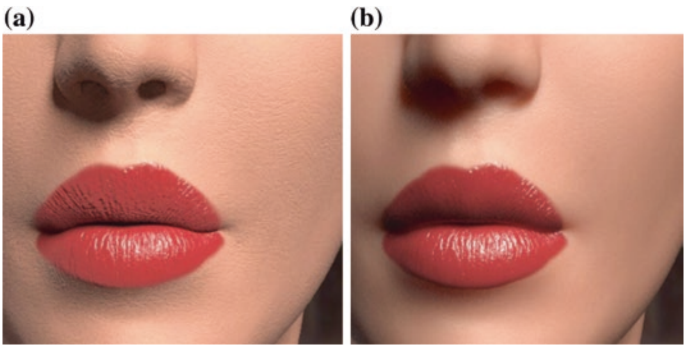

Fig. 2 Images of human face rendered with **a** BRDF and **b** BSSRDF models (Jensen 2001)

The BSSRDF (bidirectional subsurface reflection distribution function), introduced by Jensen et al., describes the relation between outgoing radiance and the incident flux, including the phenomena like subsurface scattering (SSS) (Jensen 2001). The BSSRDF describes how light is transported between any two rays that hit a surface. Figure 2a, b describes that traditional shading models give a hard skin as computer-generated look and capture the soft appearance of many natural materials, respectively. In particular, a great mathematical computation power of GPU enables to achieve high-quality game characters.

In reality, many materials are slightly translucent: Light enters the surface and is absorbed, scattered and re-emitted potentially at a different point. Skin is a good case in point; only about 6 % of reflectance is direct, 94 % is from subsurface scattering (Krishnaswamy and Baronoski 2004). The light will generally penetrate the surface and be reflected a number of times at irregular angles inside the material, before passing back out of the material at an angle other than the angle it would have if it had been reflected directly off the surface.

2 Realistic Rendering Models

2.1 Diffuse Lambert Model

Diffuse reflection causes a surface to reflect colored light when illuminated by white light. A surface that is uniform scatters light equally in all directions which means that the amount of reflected light seen does not depend on the viewer's position. So diffuse reflection is uniform reflection of light with no directional dependence for the viewer, for instance, a matte surface such as cardboard. Diffuse reflection originates from a combination of internal scattering of light, i.e., the light is absorbed and then re-emitted, and external scattering from the rough surface of the object. Such surfaces are dull or matt and the intensity of diffuse reflected light is given by Lambert's law as follows:

Intensity = (intensity of the light) * (diffuse reflectivity) * cos (angle between the surface normal and the line from the light source). An illumination model must handle both direct diffuse reflection, i.e., light coming directly from a source to a surface and then reflected to the viewer, and indirect diffuse reflection (or diffuse inter-reflections), that is light coming from a source, being reflected to a surface, then reflected to another surface, and then finally to the viewer.

Diffuse reflection is uniform reflection of light with no directional dependence for the viewer, e.g., a matte surface such as cardboard. Diffuse reflection originates from a combination of internal scattering of light, i.e., the light is absorbed and then re-emitted, and external scattering from the rough surface of the object. An illumination model must handle both direct diffuse reflection, i.e., light coming directly from a source to a surface and then reflected to the viewer, and indirect diffuse reflection (or diffuse inter-reflections), that is light coming from a source, being reflected to a surface, then reflected to another surface, , and finally to the viewer.

Oren and Nayar (1993) indicated that Lambert's model for diffuse reflection is extensively used in computation vision. It is used explicitly by methods such as shape from shading and photometric stereo, and implicitly by methods such as binocular stereo and motion detection. For several real-world objects, the Lambert model can prove to be a very inaccurate approximation to the diffuse component. While the brightness of a Lambert surface is independent of viewing direction, the brightness of a rough diffuse surface increases as the viewer approaches the source direction. The simulations showed that coefficient makes a relatively small contribution to the total radiance as the model equation.

$$
\begin{aligned}
L_r(\theta_r, \theta_i, \phi_r - \phi_i; \sigma) &= \frac{\rho}{\pi} E_0 \cos\theta_i (A + B \operatorname{Max}[0, \cos(\phi_r - \phi_i)] \sin\alpha \tan\beta) \\
A &= 1.0 - 0.5 \frac{\sigma^2}{\sigma^2 + 0.33} \\
B &= 0.45 \frac{\sigma^2}{\sigma^2 + 0.99}
\end{aligned} \tag{1}
$$

2.2 *Specular Blinn–Phong Model*

Specular reflection is useful for surfaces that have some degree of glossiness (e.g., a mirror is a perfect glossy surface) and causes light reflected from glossy surfaces to leave the surface at an angle, which is an angle that the light source beam makes with the surface. It means that the degree of specular reflection seen by a viewer depends on the viewing direction.

The physical model we implemented in a computer first-person shooter (FPS) game is a layered shading model for a physically based Blinn–Phong model (Gotanda 2010) at SIGGRAPH 2010, which was

$$f_r\left(x,\omega',\omega\right) = \frac{R_d}{\pi}(1 - F_0) + (0.0397436\,\text{shiness} + 0.0856832)\frac{F_{\text{spec}}(F_0)\left(n \cdot \frac{\omega'+\omega}{|\omega'+\omega|}\right)}{\max(n\cdot\omega', n\cdot\omega)} \quad (2)$$

where R_d is the diffuse albedo and F_{spec} (f_0) is the Fresnel function with Schlick's approximation using f_0 as the specular reflectance for the normal direction. The n is the normal vector, ω is the outgoing direction, and ω' is the incident direction. Since then, physically based shading models have been rapidly adopted in game industry.

Layered materials are very important to reproduce realistic expressions because in the real situation, there are lots of materials that have combinations of different properties consisting of different BRDFs. If artists try to reproduce these materials with a single physically based shading model, there are cases in which it would be more difficult than using an ad hoc model. This is because in an ad hoc model, the artists are able to adjust the parameters for the desired layered appearance with non-layered shading models without physical limitations. A simple solution for this issue is to implement a layered shading model. Typically, off-line renderers support very flexible layered shading models that can be combinations of any number of layers and BRDF models. However, due to performance issues, for real-time rendering on not-so-powerful GPUs, we chose only dual-layered and limited shading models. Even under these restrictions, a layered model can express much more realistic results than any other single-layered shading model.

2.3 BRDF Model

NVIDIA Corporation indicated the introduction of the modern GPU such as the GeForce 256 and GeForce2 GTS has opened the door for creating stunningly photorealistic interactive 3D content. Considering the dependence of a BRDF on the incoming and outgoing directions, the wavelength of light under consideration, and the positional variance, a general BRDF in functional notation can be written as Wynn (2000)

$$\text{BRDF}_{\lambda}(\theta_i, \varphi_i, \theta_o, \varphi_o, u, v)$$

where λ is used to indicate that the BRDF depends on the wavelength under consideration, the parameters θ_i and φ_i represent the incoming light direction in spherical coordinates, the parameters θ_o and φ_o represent the outgoing reflected direction in spherical coordinates, and u and v represent the surface position parameterized in texture space. If you are unfamiliar with spherical coordinates, they are explained in the next section. Though a BRDF is truly a function of position, sometimes the positional variance is not included in a BRDF description.

3 Proposed Method

In this paper, we have employed the BRDF model for game character reflectance, presented by the model of Jensen (Jensen 2001; Ashikhmin and Shirley 2000). First, the diffuse Lambert's model for material reflection, presented by Oren and Nayer (Wolff 1998), is widely used with simple concept in computer graphics. It is used extensively by rendering techniques such as radiosity and ray tracing. For several real-world objects; however, Lambert's model can prove to be a very inaccurate approximation to the body reflectance. While the brightness of a Lambertian surface is independent of viewing direction, that of a rough surface increases as the viewing direction approaches the light source direction (Moon et al. 2013; Wolff 1998).

Specular reflection from a rough surface is the collective specular reflection from the variously oriented microfacets producing a broader specular reflectance lobe. Although specular reflection from a rough surface can be broad in many directions, this is still a phenomenon that only involves the surface–air interface and is not considered to be diffuse reflection as sometimes confused in the computer vision community as indicated by Oren and Nayer paper (Wolff 1998). The diffuse light can be scattered in all directions. The diffuse reflection is maximized when the surface normal is aligned to the light source (Moon et al. 2013). The specular light is the highlights that are come from the reflection of shiny surfaces like a mirror. The model, proposed by Binn–Phong, surface reflectance increases with angles of incidence, but body reflectance does not decrease.

Here, we make to design 3D game character models that may overcome the simplistic light model to render objects. A BRDF model computes the relative quantity of light reflected in the outgoing direction. The BRDF is a function that takes two pairs of angle parameters as well as the wavelength and polarization of the incoming light. The two angles called elevation (δ) and azimuth (ϕ) are taken into consideration for computation of BRDF as Fig. 3 that follows anisotropic reflection properties (Kurt et al. 2010). BRDF is computed by Eq. (1) as follows:

$$P_{\mathrm{bd}}(\theta_{\mathrm{i}}, \varphi_{\mathrm{i}}; \theta_{\mathrm{r}}, \varphi_{\mathrm{r}}) = \frac{p_{\mathrm{d}}}{\pi} + P_{\mathrm{s}} \cdot \frac{1}{\sqrt{\cos\theta_{\mathrm{i}} \cos\theta_{\mathrm{r}}}} \cdot \frac{\exp\left[-\tan^2\delta\left(\cos^2\frac{\phi}{\alpha_x{}^2} + \sin^2\phi/\alpha_y{}^2\right)\right]}{4\pi\alpha_x\alpha_y}. \tag{3}$$

where related parameters are described, P_{bd}: Ward's BRDF, (θ_{i}, φ_{i}): incident light vector, (θ_{r}, φ_{r}): the reflected light vector, p_{d}: diffuse parameter, P_{s}: specular parameter, α_x: the standard deviation of the surface slope in the x direction, α_y: the standard deviation of the surface slope in the y direction,

$$L(\theta_{\mathrm{r}}, \phi_{\mathrm{r}}) = I\frac{p_{\mathrm{d}}}{\pi} L_{\mathrm{s}} P_{\mathrm{s}} \sum_{i=1}^{N} L_{\mathrm{i}}\omega_{\mathrm{i}} \cos\theta_{\mathrm{i}} P_{\mathrm{bd}}(\theta_{\mathrm{i}}, \phi_{\mathrm{i}}, \theta_{\mathrm{r}}, \phi_{\mathrm{r}}) \tag{4}$$

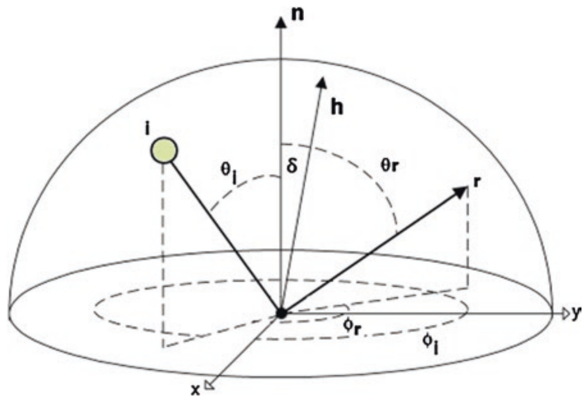

Fig. 3 Geometry structure for model expression of anisotropic reflection (Ashikhmin and Shirley 2000)

where related parameters are explained, I: the indirect radiance, L_s: the radiance from the indirect semi-specular contribution, L_i: the radiance from light source i, and ω_i: the solid angle of light source i.

4 Result and Discussion

We determine how the simulations impact and compare the rendered 3D characters with Unity 3D game engine, respectively. The system has been realized using Unity 4.2 game engine with ATI Mobility Radeon HD 4300 graphics card of 9552 GPU on Intel Core™ T-4200 that is well known of a powerful rendering engine fully integrated with a complete set of intuitive tools. For fast rendering and realistic process for 3D characters of game play, we utilized the shade code, supporting both declarative programming of the fixed-function pipeline and shader programs written in CG, allowing Unity to detect the best variant for the current video card, and if none are compatible, fall back to an alternative shader that may sacrifice features for performance. We validated and showed the real models on Fig. 4 by comparing rendered characters using Shader CG scripts. Diffuse reflection in Fig. 4a scatters light assume equally all direction called Lambert's surface. When

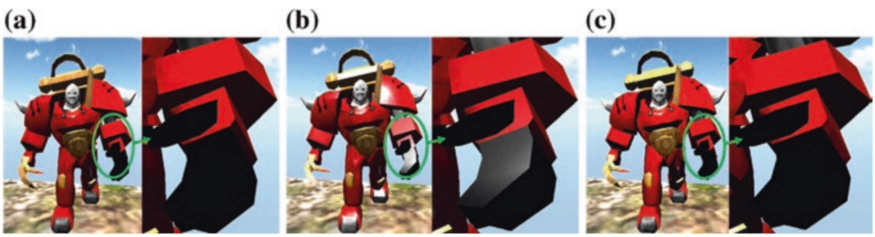

Fig. 4 Modeling characters comparison rendered with unity game engine on diffuse Lambert (**a**) and specular Blinn–Phong (**b**), and BRDF model (**c**)

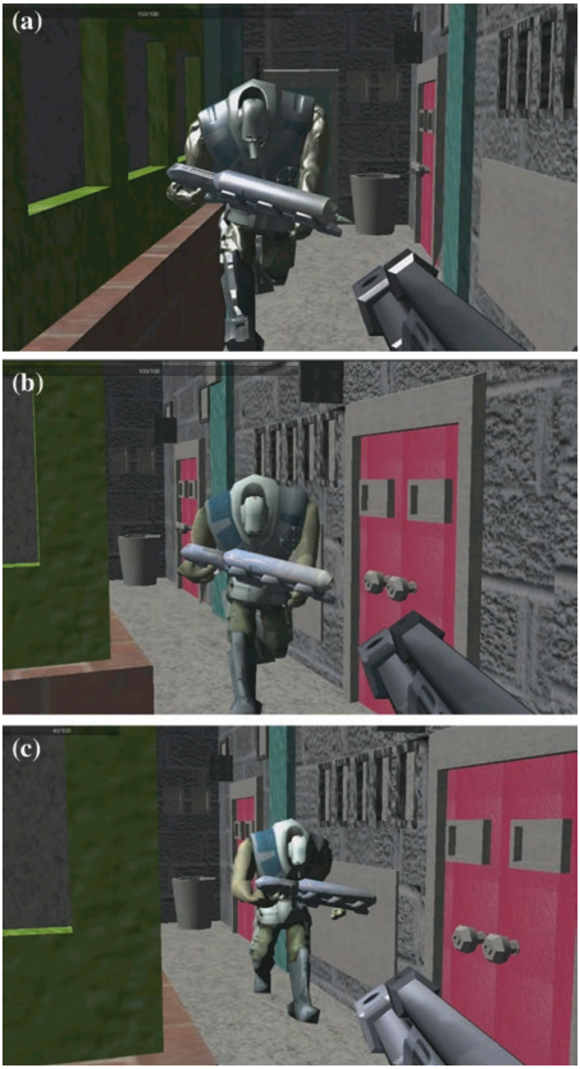

Fig. 5 Physical comparison of realistic FPS game implementation of diffuse Lambert (**a**) and specular Blinn–Phong (**b**), and BRDF model (**c**)

a light hits a rough surface of the character, it rebounds in a direction not much related to its incoming direction. We talk here about the case where lights reflect in a statistically independent direction. When the new direction is statistically independent of the old, the new direction has a very specific distribution.

Shiny surfaces of specular model have high specular coefficient used to model specular highlights in Fig. 4b. That is all well and good, but modeling true area lights are difficult even for simple cases. Since only part of the light is visible from that point on the surface of the character, then only part of the light contributes to the overall illumination. The BRDF of Fig. 4c shows the result of this process of proposed mathematical concepts and useful for opaque materials, which have a very short mean free path (Jensen 2001).

We have used exactly same lighting parameters as diffuse and specular results in Shader CG scripts-based Unity game engine. In particular, the simulated character by BRDF is practical and clearer than other methods with satisfactory results with seamless of the scene. We are really developing the effective technologies for games computing translucent complex characters.

This means that the rougher the surface, the less specular light will be reflected to the viewer. For a perfect mirror, the roughness factor would be 1; the less perfect the surface, the larger the roughness factor. Specular reflections are like blurred images of the light source being reflected on a surface. The Phong model combines ambient, diffuse, and specular reflection and calculates the intensity at a point on a surface by taking a linear combination of these three components. We implemented and simulated the mathematical algorithms of diffuse Lambert, specular Blinn–Phong, and BRDF models to use Unity engine for physical FPS game as following, Fig. 5.

5 Conclusion and Future Discussion

We have simulated and visualized to make a realistic 3D character reflectance and physical FPS game to use Unity 3D game engine with Cg scripts from the Vertex Fragment version 3.0 program. The diffuse model that proposed by Lambert, specular model that proposed by Blinn and Phong, and BRDF that proposed by Jensen have be implemented and evaluated the reflectance for an amount of the light source. The game character of specular model is brighter than other methods, but is not enough to produce realistic expression and rendering for the reflectance. We conclude that the BRDF model is motivated and preferable by practical and realistic issues with powerful GPU for game characters of real game. For the future works, a high-quality 3D rendering technology and SSS with various mathematical methods with good computation- based 3D game engine will be introduced next time for real games with more complex appearance and mathematical concept considering multiple layers of various materials.

Acknowledgements This research was partially funded by Korea Government, Institute for Information and Communications Technology Promotion, IITP (CiMR: Physically based Cinematic Material Rendering Techniques optimized for Gameplay, No 10043453) and supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2012R1A1A2001091).

References

Ashikhmin, M., & Shirley, P. (2000). An anisotropic phong BRDF model. *Journal of Graphics Tools, 5*(2), 25–32.

Gotanda, Y. (2010). Practical implementation of physically based shading models at tri-Ace. *SIGGRAPH*.

Jensen, H. W., et al. (2001). A practical model for subsurface light transport. In *Proceedings of SIGGRAPH 2001, Los Angeles*, August 2001 (pp. 511–518).

Krishnaswamy, A., & Baronoski, G. V. G. (2004). A biophysically-based spectral model of light interaction with human skin. *Computer Graphics Forum, 23*(3), 331. doi:10.1111/j.1467-8659.2004.00764. (Blackwell Publishing).

Kurt, M., Szirmay-Kalos, L., & Kˇriv´anek, J. (2010). An anisotropic BRDF model for fitting and Monte Carlo rendering. *ACM SIGGRAPH Computer Graphics, 44*(1), 3.

Marschner, S. R. (1998). Inverse rendering for computer graphics. Ph.D. Thesis, Cornell University.

Matusik, W., et al. (2005). Experimental analysis of BRDF models TR2005-151, MIT 20139.

Moon, S., et al. (2013). Cinematic wound synthesis optimized for real-time gameplay. *International Journal of Software Engineering and Its Applications, 7*(1), 221–228.

Oren, M., & Nayar, S. K. (1993). Generalizing Lambert's law. In *Proceeding of the DARPA Image Understanding Workshop, Washington,DC* (pp. 1025–1030).

Wolff, L. B., et al. (1998). Improved diffuse reflection models for computer vision. *International Journal of Computer Vision, 30*(1), 55–71.

Wynn, C. (2000). An introduction to BRDF-based lighting. Santa Clara: NVIDIA Corporation.

Play It Safe; A Situational Game for Occupational Safety

Bard O. Wartena, Derek A. Kuipers and Hylke W. van Dijk

Abstract This chapter describes the design choices and theoretical constructs that have led to the development of an occupational safety game, going by the name Play it Safe. Play it Safe is a tower defense game that uses situational data collected by employees, during their daily work, to impact the parameters of the video game. These data are gathered through a safety campaign named, Count Yourself Lucky (CYL) to quantify the amount of times employees used the supplied safety technique [Stop, Think, Act, Review (STAR)]. Play it Safe, as a form of situational gaming and as a behavioral change support system (BCSS), through metaphorical re-contextualization attempts to create parameters for similar decision making encountered in the work environment and implicitly reinforce the training of the STAR protocol and conservative decision making. Play it Safe aims to improve employees' situational awareness, creating a shared mental model and bottom–up accountability, meant to improve and align (shared) safety behaviors.

Keywords Occupational safety · Serious games · Situational gaming · Behavior change support system · Situation awareness · STAR

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O. Sourina et al. (eds.), *Subconscious Learning via Games and Social Media*,
Gaming Media and Social Effects, DOI 10.1007/978-981-287-408-5_2

1 Introduction

Accidents happen; however, responsible employers are constantly attempting to create safer environments by improving measures to diminish the number of mishaps and accidents. The incident frequency rate (IFR), the main measure of safety in industry, varies among sectors, as do the risk factors inherent in certain jobs. Measures to maximize safety (knowledge, skills, protocols, conditional safety structures, and safety interventions) contribute to lowering IFR. Not all companies are proactive when it comes to safety or equipped with ample precautions in the work environment and culture. However, even companies at the top of the HSE culture ladder who have taken ample precautions, have a finite effect on safety (DePasquale and Geller 2000).

Even when equipped with all the right tools in the correct environment, the human factor can be the cause of failure (Reason 1990a); as routine kicks in, vigilance checks out. To bring safety awareness to the next level, serious gaming might prove to be a valuable tool in employees' toolboxes. Serious gaming offers a new and engaging way to demonstrate an adaptive interaction with the immediate relevance of situations and contexts from the work floor. In this way, serious gaming can mix reality with an open practice environment in an emergent feedback loop that triggers the players to have safety, which is forefront in the mind at the moments that warrant vigilance, while improving the safety awareness as well as the safety environment. This all through noticing and registering lapses or slips and their probable causes.

This chapter describes the trials and tribulations of the design and development process of a serious game, named Play it Safe, with the goal of behavioral change toward occupational safety aspects inherent to dynamic high-risk jobs and environments. Part two describes on a short outline of occupational safety trends and related work in the field of serious gaming, as well as a short outline of the focus of Play it Safe. Part two focuses on the design process of and implications of situational gaming, part three focuses on behavior change support systems (BCSS), Stop, Think, Act, Review (STAR), and the surrounding safety campaign; Count Yourself Lucky (CYL). Part four describes the video game Play it Safe the involved gameplay and game mechanics as the goals of the game. The final part discusses the possibilities of situational games and the initial experiences with Play it Safe and the CYL campaign.

2 Safety Matters

After physiological needs, the second step in the hierarchy of needs (Maslow 1943) on Maslow's pyramid is safety. Occupational safety has been a priority in the workplace since the beginning of the nineteenth century. Over the last decade, safety structures placed great emphasize on rule-based and behavior-based safety. This approach is described as Model 1 (Hale and Borys 2013), a predominantly top–down approach. In Model 1, workers attain knowledge and skills and act as rule-based operators who follow golden rules that are strictly enforced top–down. In Model 2, these same rules apply, however, they are seen as guidelines for the competent professional (Hale and Borys 2013). They are dynamic and rein-forced bottom–up, resulting in safety solutions coming from employees instead of management. Independent of the position of safety in an organization, the safety climate and culture of the company implementing the safety interventions has been found to be a key indicator for the attempted intervention (Hale et al. 2010). In addition to the safety climate and culture, a large part of safety science focuses on conditional safety.

Conditional safety entails making the environment as well as the equipment used as safe as possible. This is realized by providing instructions, use of warning signs and protective clothing, making the equipment and the work environment as safe as possible. The primary cause of error and (near) accidents is the human operator. Therefore in safety science, Human Error (Reason 1990b) modeling, based on the underlying strengths and limitations of the human operator, is used to design protocols, rules, machinery, and overall resilient systems to minimize accidents. Unsafe acts can be divided into execution errors (correct plan, wrong execution) and planning errors (incorrect plan). Execution errors can be divided into slips (attention failure) and lapses (memory failure), planning errors can be either rule-based or knowledge-based mistakes (unintentional decision to act against rules or standards) and violations (deliberate decisions to act against rules or standards). To gain further understanding of human error, Rasmussen (1983) developed the human performance model, consisting of the following levels.

- **Skill-based behavior**: an automatized sensory-motor performance that one can perform without conscious control.
- **Rule-based behavior**: based on stored procedures, gained through experience and learning. It works through recognition, association of state/task and then using the stored rule for the task.
- **Knowledge-based behavior**: when confronted with unfamiliar situations, where explicit thought is necessary to develop a plan, exercise it and see if it works. It works through identification, decision of task, and planning.

The different levels of reasoning can be accessed simultaneously, but are triggered by different aspects of contexts and situations. The mental model that workers have of the situation around them, i.e., Situation Awareness (SA, Fig. 1) (Endsley 1995), and the decisions made depending on that situation, are highly influenced by the performance levels used by the operators. SA came from military aviation (Endsley 1988) but since then has been used and researched in a wide range of contexts and fields. Endsley's definition of SA is the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future (Endsley 1995). This process is automatic. However, perception, comprehension, and projection of how a situation will evolve, depending on the action a worker is planning to undertake, is vital in planning and undertaking an action. When making the decision to perform

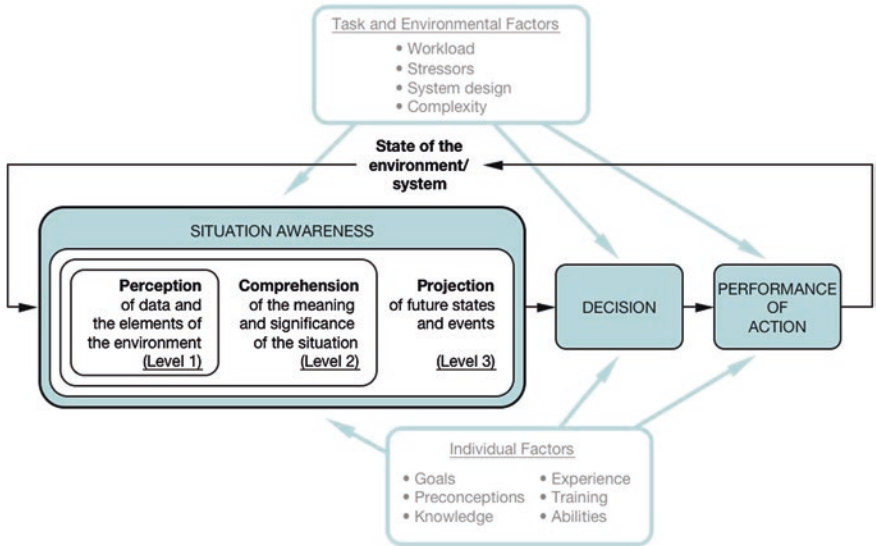

Fig. 1 Adapted from Endsley's situation awareness model [(Endsley 1995), model used from www.situationawareness.nl]

a task, it is vital to base that decision on a correct state of the necessary elements in the environment around you. Therefore, a review of the action undertaken and possible deviations of the projected state of the environment around you are relevant for vigilance and safe behaviors. Besides an individuals SA, there is also Team or Shared SA (TSA/SSA) (Salas et al. 1995; Salmon et al. 2008), the understanding between team members of each other's mental model of the situation. A high level of Shared SA between team members provides a work environment in which the needs and way of approaching tasks and situations of others are understood and taken into account (Salas et al. 1995; Salmon et al. 2008). Therefore, a high SA is a vital part of safety on the work floor, both individually as well as in a team (Leonard et al. 2004) and will produce an increase in workplace safety (Stanton et al. 2001).

2.1 Simulations and Games for Occupational Safety

Games and simulations for occupational safety have been used in a variety of fields with a wide range of goals, including the following:

- Virtual training in construction plants (Guo et al. 2012),
- Virtual training to increase SA during cardiopulmonary resuscitation (Felländer-Tsai 2014),
- Evacuation drills (Chittaro 2012; Maruejouls and Chopinaud 2013; Silva et al. 2013),

- Hazard recognition (Mayer et al. 2013),
- Intervention to reduce work stress and raise work engagement (Wiezer et al. 2013),
- Training and education of operations on ships and offshore platforms (Bruzzone et al. 2013),
- Design in construction (Dawood et al. 2012),
- Training for working at heights for mine sites (Stothard and Van Den Hengel 2010).

These are predominantly simulation games for safety training, depending heavily on a match between content and context, a high level of fidelity and a low level of play (or no play at all). Problems with these simulations are that they:

- almost automatically create a mismatch between the desired blend of entertainment and learning (Ritterfeld and Weber 2006) within the game, missing out on the positive effects of entertainment on learning (Gee 2003).
- require extensive training needs analysis (TNA) methodologies (Bee and Bee 2003).
- can only be used for specific goals and situations. A created scenario within a simulation will only be useful for a specific target group and will only encompass limited tasks and environments. In an occupational safety game, it would be impossible to simulate and program every possible accident or near accident, inherent to the particular task in the particular work sector.

Therefore, instead of focusing on the outcomes of specific risks of specific task-related accidents, the more practical and feasible goal might be to intervene in the mental model an employee applies to approach general tasks, environments, and situations.

2.2 *Play It Safe*

The Play it Safe project was established to address the needs of several small- and medium-sized enterprises working in high-risk and highly dynamic task environments. Each company faces a similar dilemma; despite specific rule-based behavior and the specific task-related knowledge being available and reinforced, accidents still occurred.

Play it Safe aims at creating top of mind safety awareness for workers in the construction and maintenance industry. The workers operate in small teams with variable constitution and at varying locations. Obviously, these workers know the safety rules, but in the heat of the moment, slips, lapses, and errors occur. Play it Safe focuses on preventing accidents using a cognitive intervention called STAR, for procedural tasks, focusing on the context outside the game rather than the content within the game by the use of situational data retrieved through the CYL campaign.

3 Situational Gaming

Situational games (van Dijk and Voigt 2012) are games in which real-life data are used to affect the parameters of the game, often by the use of cross- and transmedial applications. The idea is to gather situational data and play the game in close proximity or on the location and in the context where the initial problems arose. The basic assumption of the effectiveness of a situational game for serious purposes is that situation provides an authentic setting that engages a player, helps to realize the logic, and triggers the player into action. The authenticity provides the necessary meaning and appreciation. The situation plays a role in multiple dimensions of persuasion, i.e., striving to persuade players to change their behavior. The framework helps to make the role and possibly the impact of situation explicit during the design of serious games. Situation contributes in a positive way in reaching the underlying objective of the game. For Play it Safe, situational gaming was used to attempt increase safety awareness among workers. Eventing, thus taking real-life events into the gameplay, is suggested to be a good starting point for any situational game (van Dijk and Voigt 2012). Situation and context determine the effect of a trigger. Triggers, when carefully timed and chosen, provide the spark to activate a change in behavior (Fogg 2009). By adhering to a person's situation, triggers become authentic and actions become meaningful (Salen and Zimmerman 2005). The player can identify itself with the matter.

The use of situational data in Play it Safe reflects the belief that transfer should be considered as a design parameter. Kuipers et al. (2013) argue that core principles (in this case the STAR protocol) in a game should be carefully designed in conjunction with a specific transfer type in mind, aligning the players' needs and abilities, including sociocultural aspects, serious goals, and topic characteristics. The process of translating situational data into game elements is called re-contextualization, defining the pinnacle of serious game design: The subjective soundness and recognize ability of the re-contextualization is essential for transfer of safety awareness. By introducing real-life data in the game, they link the target context to the learning context (the game), enabling transfer between similar, but not identical contexts.

Near transfer can be categorized under literal transfer: transfer by the means of similarity, as opposed by figural transfer: transfer as a result of using some part of existing world knowledge for thinking about a particular problem. The game transfer model projects a game as a conceptual continuity in a continuum, stretching from mimetic simulation to abstract gameplay (see Fig. 2). Within boundaries, the position of the game on the game transfer model (Kuipers et al. 2013) has to correspond with design choices dedicated to facilitate transfer in a situational game aiming at raising safety awareness among employees through re-contextualization of the STAR protocol and situational input.

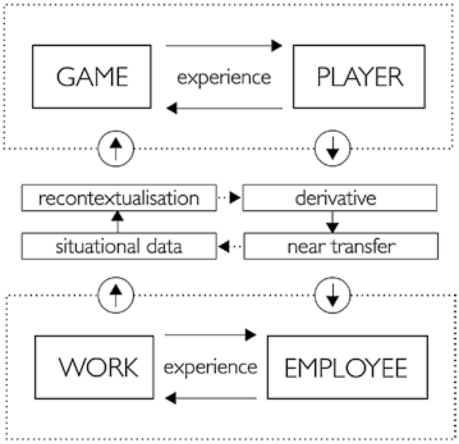

Fig. 2 This model describes the desired transfer model of the game and the reality outside the game as experienced by the player

4 Behavior Change Support System; Count Yourself Lucky with STAR and Play It Safe

A BCSS was defined by Oinas-Kukkonen (Gemert-Pijnen et al. 2013; Oinas-Kukkonen 2013) as:

> a socio-technical information system with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying with-out using coercion or deception.

The computer game Play it Safe is not a stand-alone intervention, to be a BCSS, it needed a transmedial function (Dena 2010) as a trigger to create the situational input and a complementary tool for assessment and participation to gather this input. Through the project, state-of-the-art sensors, and other elaborative options were proposed; however, they proved to be infeasible in a highly dynamic high-risk work environment. Many companies, for instance, did not allow smartphones because the digital disruptions could prove dangerous during working hours. Therefore, an analogue solution was found.

4.1 STAR: Stop, Think, Act, Review

Play it Safe uses the safety intervention STAR combined with situational aspects, i.e., events from the work floor are integrated to have effect in the game. STAR is a mental protocol to facilitate safety awareness. This mental protocol attributes the creation of awareness of a situation to three entangled processes: perception, comprehension, and projection. These processes attribute the enclosing environment, the physical context. The mental model is completed with a decision-making process and an effectuation of an intended action. The action obviously affects the

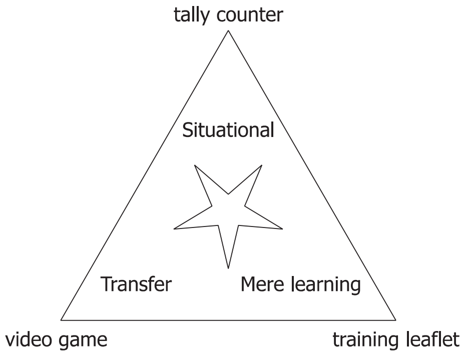

Fig. 3 The ubiquitous workings of the STAR protocol as a. a situational safety detection tool, b. a game mechanic, and c. the textual intervention

state of the immediate environment. STAR is being and has been used in several fields (Dickerson et al. 2010; Paradies 2007; Yates et al. 2005) and is closely modeled on SA (see Fig. 5).

STAR has different modes of use (see Fig. 3):

- as a **standard protocol** to be used with every task (*skill-based behavior*)
- as a **critical task protocol** to be used only with tasks that are deemed to be a risk and require full attention (*rule-based behavior*)
- As an **emergency protocol** to be used when something goes wrong and one finds him/herself in an unfamiliar situation (*knowledge-based behavior*)

4.2 Count Yourself Lucky with STAR

In the implementation of Play it Safe, STAR was utilized and integrated in all of the aforementioned modes. STAR was also used to detect deviations from the projected outcome of situations and record these with a tally counter (CYL), and that amount was then used as an in-game reward. During the Play it Safe campaign, STAR was used as a safety protocol and detection tool in the workplace (see Fig. 3):

- A **safety protocol** to use while performing critical tasks and after some practice become part of skill-based, rule-based, and knowledge-based behavior. This was attempted through mere learning on a leaflet and demonstrations.
- A **detection tool** for situations that deviated from the projected outcome of an action (through the Review in STAR), of oneself or others. These deviations where used as the input of the CYL score, keeping score daily on a tally counter.

The motivation to use one's tally counter in the CYL campaign (besides bottom–up accountability and communication culture) is to gain an in-game advantage. Through the use of an electromagnetic pulse (EMP) in the game that makes it possible to progress with more ease in the game. The EMP, however, is a re-contextualized STAR protocol that lets the players do two essential things, in the game:

1. **Assess** when the in-game situation becomes too dynamic to project a clear outcome, i.e., being unable to project the situation state after the action is undertaken.
2. While using the EMP, players are forced to **Review** the situation and reorder the elements in the situation and the appropriate actions that can resolve it.

The ubiquitous implementation of STAR (see Fig. 3) trains players outside of the game to use a mental protocol to integrate into their daily working behavior, while at the same time acting as a detection tool for situations that deviate from their projected outcome. This facilitates the players to take a closer look at their daily working environment and the boundaries to work safely within them, as well as noticing the limitations or shortcomings of conditional safety structures. The CYL campaign is motivated by the in-game reward system, while in the game the STAR reinforces the already learned protocol in unrealistic situations that train the players SA.

Because the video game is played during lunch breaks in the workplace, the situations become more tangible and the implementation of the CYL score can become a trigger to discuss workplace safety among colleagues. Furthermore, because all colleagues are using the same protocol, the Shared/Team SA is trained and barriers in individual SA can be discussed as requirements for a high Team SA, creating an open communication culture where bottom–up initiatives are harnessed.

5 Play It Safe: The Computer Game

Play it Safe (see Fig. 4) is a touch screen tablet-based video game of the tower defense genre, the objective of a tower defender is to protect ones base against an enemy that wants to steal the supplies stored in that base. To succeed in this objective, the player builds towers, tactically placed around the area to kill the stream of enemies. Play it Safe differs from traditional tower defense games, with the addition of workers that build and fix the towers and the possibility to use an EMP as a strategic advantage. The story behind the game is that a spaceship has crashed upon a distant planet that is inhabited by bug-like aliens who are attracted to energy cores that you need to power and repair the ship. To defend the crew and ship against the bug-like aliens, guard towers are built that automatically shoot the bug-like mechanized aliens.

5.1 Gameplay

When the player starts the game, he/she can build as many towers as time allows, before a first wave of enemies arrives. The arrival of enemies is usually preceded by an alarm, but as with any action in the game, there are exceptions that keep players

Fig. 4 A screenshot of Play it Safe being played

on their toes. Towers are built by workers, when chosen workers have a primary objective to build, towers will be finished quicker. When towers are built, workers can be placed in the towers so that alien robots will not hurt them. After or during these attacks, they can be directed to fix broken towers; however, there is a risk they will get hurt. Enemies approach in waves, so usually there is time after a first wave to regroup and fix or build extra towers. During waves, pressure builds and it gets harder and harder to keep control over workers while keeping track of the states of the environment as well as enemies. It is possible to use the EMP mechanic to regain control over the game environment and regain situational leadership over the workforce. If the player keeps the energy cores in the game, he/she wins, if the player loses all of them he/she loses. Extra points and badges can be won for using workers for their primary objectives, using the EMP and not letting your workforce get hurt.

5.2 Game Objects

Energy Cores

The energy cores are the main assets in the game. Workers try to defend them and the enemies attempt to steal them. They are kept in the base spaceship.

Base

The home base of the game avatars is a spaceship wherein the energy cores are stashed. Members from the workforce enter the game through the base when the player starts to build towers.

Enemies

There are two kinds of mechanized bug-like aliens. Both types can steal energy cores; however, the eaters will attack towers and workers on their way to steal the cores, whereas the collectors will go straight for the energy cores.

1. **Eaters**, their main objective is to destroy towers, by gnawing on them.
2. **Collectors**, their main objective is to walk into the base pick up an energy core and walk away with it, toward their own base.

Workers

To create towers, it is necessary to have workers to built and restore the before-mentioned towers. There are three types of workers.

1. **Builders** build and repair towers.
2. **Firemen** extinguish towers when they are on fire.
3. **Mechanics** fix mechanical damage in the towers.

The player can distinguish between the three types by the visual appearance of the workers. Their entire workforce has a single primary objective as well as a fitting suit to perform this primary task. It is possible to assign tasks to avatars that are not their primary objectives; the avatars will, however, be slower and less successful in performing these non-primary tasks and thus in more danger. When either fire, radiation from a tower or an enemy hurts a worker, their health state declines and they eventually die. To heal workers, they can be directed into an undamaged tower, where they will be healed.

Towers

Before building a tower, the integrity of the ground to be built on must be checked. The higher the integrity of the ground, the more resilient the tower will be against enemy attacks. Towers can be placed anywhere on the map and shoot intruding enemies on sight. Whenever enemies damage towers, their states deteriorate and markers (electricity sparks or fire) are visible before they eventually collapse or are repaired. The workers can hide in the tower from enemies closing in on them.

5.3 Game Mechanics

Count Yourself Lucky score

The player is asked to fill in the day score of the previous working day on the start screen of the game. This score is used to determine the amount of EMPs available to the player in the game.

Ground inspection
To build towers, the integrity of the ground can be checked with a special option to use a looking glass that gives the percentage of the ground integrity. This influences the towers deterioration process.

***Electro Magnetic Pulse* (*EMP*)**
The EMP can be used either to freeze all enemies as well as workers or to just freeze their enemies, depending on successfully using the touch screen hold mode on the intended icon. In either situation, it gives the player time to use STAR and gain a new oversight in the game, which can be lost due to the pace in the game.

5.4 Transformational Learning

Through the use of metaphorical re-contextualization (Fogg 2009), Play it Safe uses near transfer to create a metaphorical low-fidelity game world in which less explicit and extensive parameters apply in comparison to the workplace. In the Game world, there are observable (enemies) and non-observable (ground integrity) threats as well as simulated time pressure, which forces the players to keep reassessing their plans and actions with regard to the ever changing the environment. Not to recognize specific or realistic threats, but to gain insight and perspective on the need for an oversight into the aspects of a situation, i.e., situation awareness and the necessity of conservative decision making within a dynamic environment (Fig. 5).

Mitgustsch (2011) distinguishes three stages of learning through serious games aligning with Bateson (1972) stages of learning; (1) in, (2) through, and (3) beyond the game. In case of Play it Safe, the transformational learning process is as follows:

- In the game, the player carries out random tasks at hand and leads a workforce that can change into various states. Through trial and error, the player reacts to the game environment and learns to play the game.
- Through the game learning, the player will learn what the limits and barriers of their situation awareness are and when they reach these parameters.
- Beyond the game learning, this stage is expanded to real-life contexts outside of the game. The player recognizes the barriers for high situation awareness in their daily working environment and is continuously training the use of STAR in skill-, rule-, and knowledge-based behaviors to reduce errors, slips, and lapses and ultimately the companies' IFR.

SA and STAR are used to overcome the in-game challenges without being explicitly taught, creating an implicit training tool. Play it Safe the computer game combined with CYL and the explicit STAR training, together function as a transmedial BCSS that attempts to abide by the dynamic demands of the sociotechnical environment.

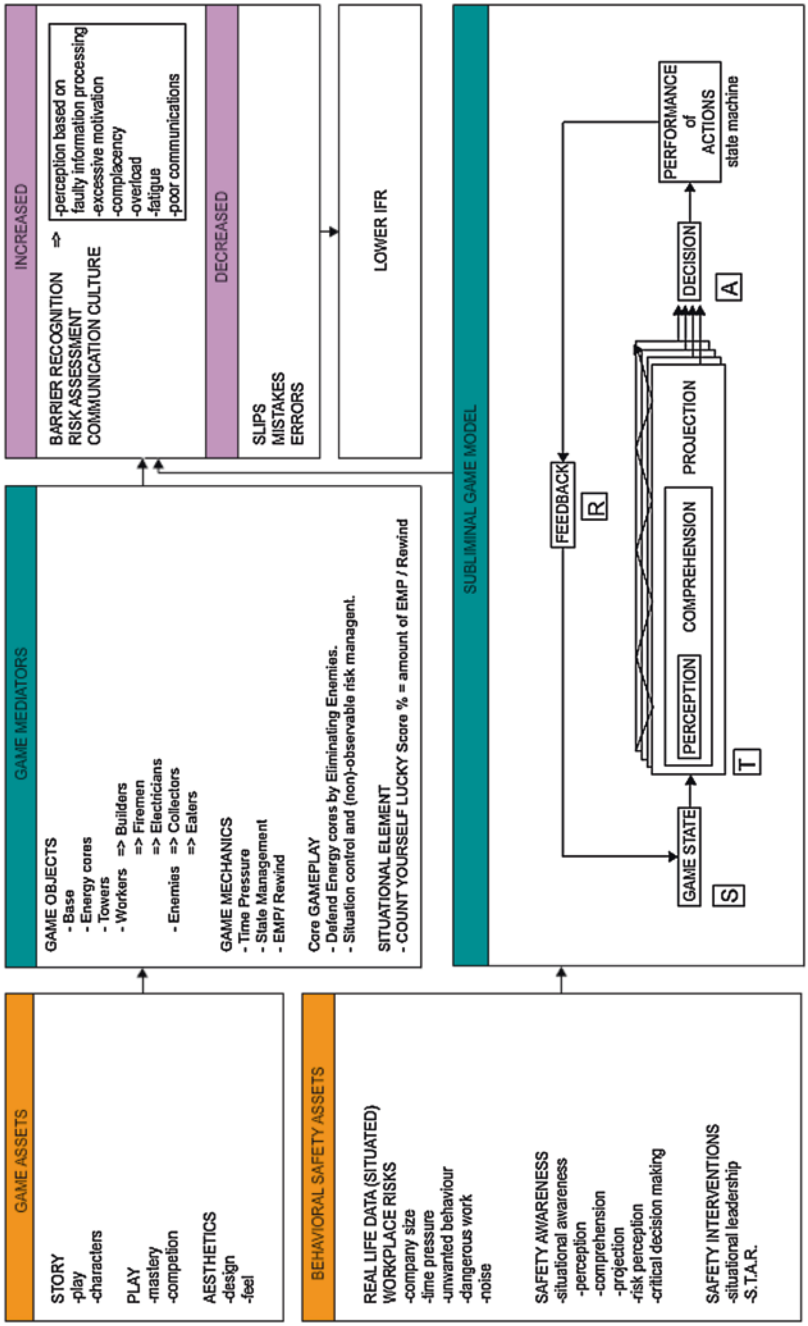

Fig. 5 The proposed schematic behavior and attitude-changing model, adapted from Thompson et al. (2010)

6 Discussion

Because of the ubiquitous nature and transmedial character of the BCSS, a schematic breakdown of the active elements is given. Play it Safe implements four modes of use (Wartena et al. 2014) of one BCSS through situational gaming:

- As an intervention, STAR is implemented to attempt to improve individual SA and Team SA. Through the use in and outside of the game, the recognition of a loss of overview or cognitive overload in working situations is trained and reinforced.
- As a trigger, through the use of the CYL campaign, wherein the employee, through the use of a tally counter, keeps track of the situations in which he/she lost the overview of the situation.
- As an assessment, for employees and safety leaders through the scores of the game, as well as the individual or shared CYL scores, which both act as a self-assessment and give feedback about the amount of unsafe events on the work floor.
- As a tool for participation, through the CYL campaign empowering users to inform safety managers about unsafe practices, equipment, behaviors, or specific situations or context.

This transmedial BCSS aims to impact compliance toward safety rules, lasting behavior change through creating a Team SA by using the mental protocol STAR and ultimately an attitude change in creating a bottom–up safety culture, making safety a tangible concept that all members of a team are involved in and feel accountable for.

Play it Safe harnesses the motivating and rewarding aspects of in-game appraisal for out-game actions (CYL), as well as implicitly reinforcing the actions outside of the game, in the game itself. Thereby, Play it Safe can be considered a recursive BCSS, not to create high vigilance at all time, but to recognize the barriers inherent to an incomplete view of a situation. Performing knowledge-based behavior while wrapped up in other tasks can be dangerous at any time (Verwey 2004); therefore, an insight into the precursors of cognitive overload can be a powerful tool for safety awareness.

In the preliminary trials, safety leaders, on site of the respective companies, noticed an increase in interactions and respective tally counters scores when group activities took place than when solitary tasks were performed. The CYL campaign seemed to increase the communication culture concerning safety matters during these group activities. The simple task of making a conscious note can be a tangible trigger to enhance situated cognition through situated play (Rambusch 2006). As a situational game, Play it Safe makes the environment the trigger in and outside of the game, utilizing safety on the work floor through the game.

Acknowledgments The work described in this paper has been supported in part by the RAAK SIA project Play it Safe (273). The authors gratefully thank the project members for the numerous discussions and their valuable contributions to the design and testing of Play it Safe.

References

Bateson, G. (1972). *Steps to an ecology of mind: Collected essays in anthropology, psychiatry, evolution, and epistemology*. Chicago: University of Chicago Press.

Bee, F., & Bee, R. (2003). *Learning needs analysis and evaluation*. London: Chartered Institute of Personnel and Development.

Bruzzone, A. G., Massei, M., Solis, A. O., Poggi, S., Bartolucci, C., & Capponi, L. D. A. (2013). Serious games as enablers for training and education on operations on ships and off-shore platforms. In *Proceedings of the 2013 Summer Computer Simulation Conference* (p. 36). Society for Modeling & Simulation International.

Chittaro, L. (2012). Passengers' safety in aircraft evacuations: Employing serious games to educate and persuade. In *Persuasive technology. Design for health and safety* (pp. 215–226). Heidelberg: Springer.

Dawood, N., Miller, J., & Yabuki, N. (2012). Incorporating H&S into design and construction: the case for integrating serious games engines technologies and 4D planning for collaborative work. In *Cooperative design, visualization, and engineering* (pp. 255–263). Berlin, Heidelberg: Springer.

Dena, C. (2010). Transmedia practice: Theorising the practice of expressing a fictional world across distinct media and environments (Doctoral dissertation, University of Sydney).

DePasquale, J. P., & Geller, E. S. (2000). Critical success factors for behavior-based safety: A study of twenty industry-wide applications. *Journal of Safety Research, 30*(4), 237–249.

Dickerson, J. M., Koch, B. L., Adams, J. M., Goodfriend, M. A., & Donnelly, L. F. (2010). Safety coaches in radiology: Decreasing human error and minimizing patient harm. *Pediatric Radiology, 40*(9), 1545–1551.

Endsley, M. R. (1988). Situation awareness in aircraft systems: Symposium abstract. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 32, pp. 96–96). California: SAGE Publications.

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 37*(1), 32–64.

Felländer-Tsai, L. (2014). Using virtual world training to increase situation awareness during cardiopulmonary resuscitation. *Medicine Meets Virtual Reality 21: NextMed/MMVR21*, *196*, 83.

Fogg, B. J. (2009). A behavior model for persuasive design. In *Proceedings of the 4th International Conference on Persuasive Technology* (p. 40). ACM.

Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Computers in Entertainment (CIE), 1(1)*, 20–20.

Gemert-Pijnen, J., Reitberger, W., Langrial, S., Ploderer, B., & Oinas-Kukkonen, H. (2013). Expanding the research area of behavior change support systems. In *Proceedings of First International Workshop on Behavior Change Support Systems (BCSS 2013).*

Guo, H., Li, H., Chan, G., & Skitmore, M. (2012). Using game technologies to improve the safety of construction plant operations. *Accident Analysis and Prevention, 48*, 204–213.

Hale, A., & Borys, D. (2013). Working to rule, or working safely? Part 1: A state of the art review. *Safety Science, 55*, 207–221.

Hale, A. R., Guldenmund, F. W., Van Loenhout, P. L. C. H., & Oh, J. I. H. (2010). Evaluating safety management and culture interventions to improve safety: Effective intervention strategies. *Safety Science, 48*(8), 1026–1035.

Kuipers, D. A., Wartena, B. O., Dijkstra, A., Prins, J. T., & Pierie, J. P. E. (2013). Design for transfer. In *Serious games development and applications* (pp. 239–246). Heidelberg: Springer.

Leonard, M., Graham, S., & Bonacum, D. (2004). The human factor: the critical importance of effective teamwork and communication in providing safe care. *Quality and Safety in Health Care, 13*(suppl 1), i85–i90.

Maruejouls, S., & Chopinaud, C. (2013). IMOSHION: A simulation framework using virtual intelligent agents for workplace evacuation in case of emergency situation. In *Advances on practical applications of agents and multi-agent systems* (pp. 304–307). Heidelberg: Springer.

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review, 50*(4), 370.

Mayer, I., Wolff, A., & Wenzler, I. (2013). Learning efficacy of the 'hazard recognition' serious game. In *Serious games development and applications* (pp. 118–129). Heidelberg: Springer.
Mitgutsch, K. (2011). Serious learning in serious games. In *Serious games and edutainment applications* (pp. 45–58). London: Springer.
Oinas-Kukkonen, H. (2013). A foundation for the study of behavior change support systems. *Personal and Ubiquitous Computing, 17*(6), 1223–1235.
Paradies, M. (2007). Positive vs. negative enforcement: Which promotes high reliability human performance. In *2007 IEEE 8th Human Factors and Power Plants and HPRCT 13th Annual Meeting* (pp. 185–188). IEEE.
Rambusch, J. (2006). The embodied and situated nature of computer game play. In *Workshop on the cognitive science of games and game play.*
Rasmussen, J. (1983). Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. *IEEE Transactions on Systems, Man and Cybernetics, 3*, 257–266.
Reason, J. (1990a). The contribution of latent human failures to the breakdown of complex systems. *Philosophical Transactions of the Royal Society B: Biological Sciences, 327*(1241), 475–484.
Reason, J. (1990b). *Human error*. Cambridge: Cambridge University Press.
Ritterfeld, U., & Weber, R. (2006). Video games for entertainment and education. In P. Vorderer & J. Bryant (Eds.) *Playing video games: Motives, responses, and consequences.* Mahwah, NJ: Lawrence Erlbaum Associates, pp.399–413.
Salas, E., Prince, C., Baker, D. P., & Shrestha, L. (1995). Situation awareness in team performance: Implications for measurement and training. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 37*(1), 123–136.
Salen, K., & Zimmerman, E. (2005). Game design and meaningful play. In J. Raessens & J. Goldstein (Eds.), *Handbook of computer game studies*. MIT Press, Cambridge Massachusetts, pp. 59–79.
Salmon, P. M., Stanton, N. A., Walker, G. H., Baber, C., Jenkins, D. P., McMaster, R., & Young, M. S. (2008). What really is going on? Review of situation awareness models for individuals and teams. *Theoretical Issues in Ergonomics Science, 9*(4), 297–323.
Silva, J. F., Almeida, J. E., Rossetti, R. J., & Leca Coelho, A. (2013). Gamifying evacuation drills. In *8th Iberian Conference on Information Systems and Technologies (CISTI)* (pp. 1–6). IEEE.
Stanton, N. A., Chambers, P. R. G., & Piggott, J. (2001). Situational awareness and safety. *Safety Science, 39*(3), 189–204.
Stothard, P., & Van Den Hengel, A. (2010). Development of serious computer game based training module and its integration into working at heights mine site induction—Part I. *Mining Technology, 119*(2), 68–78.
Thompson, D., Baranowski, T., Buday, R., Baranowski, J., Thompson, V., Jago, R., & Griffith, M. J. (2010). Serious video games for health: How behavioral science guided the design of a game on diabetes and obesity. Simulation & gaming. 41, 587–606.
van Dijk, H. W., & Voigt, E. H. (2012). *Situational games; a white paper*. Technical report, NHL University of Applied Sciences. http://www.mediafutureweek.nl/wp-content/uploads/2012/05/whitepaper-Situational-Games-NHL.pdf. (invited white paper for Media Future Week).
Verwey, W. B. (2004). Psychologische functieleer en cognitieve ergonomie: Een siamese tweeling? *Tijdschrift voor Ergonomie, 29*(2), 4–9.
Wartena, B., Kuipers, D., van Dijk, H. W. (2014). Ludens Modi Varietas; A Gamearchitecture inspired design approach for BCSS. In *Proceedings of the Second International Workshop on Behavior Change Support Systems (BCSS2014)*, *Padova, Italy*, May 22, 2014.
Wiezer, N., Roozeboom, M. B., & Oprins, E. (2013). Serious gaming used as management intervention to prevent work-related stress and raise work–engagement among workers. In *Digital human modeling and applications in health, safety, ergonomics, and risk management. Human body modeling and ergonomics* (pp. 149–158). Heidelberg: Springer.
Yates, G. R., Bernd, D. L., Sayles, S. M., Stockmeier, C. A., Burke, G., & Merti, G. E. (2005). Building and sustaining a systemwide culture of safety. *Joint Commission Journal on Quality and Patient Safety, 31*(12), 684–689.

Capacity Building in Water with Serious Games

Chengzi Chew, Gareth James Lloyd and Eske Knudsen

Abstract Serious games are not a new concept, but serious games using real-life data-coupled with real-time modelling and combining the model results with social and economic factors opens up a new paradigm for active stakeholder participation and education. Aqua Republica combines a game layer with a water allocation model, MIKE HYDRO, to create an interactive, realistic virtual environment where players play the role of a democratic leader of a river catchment. Different versions of the game are developed to support different interests. Examples include a version for educating school-age children, a version for stakeholder participation workshops and a version for raising awareness

Keywords Serious games · IWRM · Trans-boundary · Governance · Capacity building · ICT

Serious games are not a new concept, but serious games using real-life data—coupled with real-time modeling and combining model results with social and economic factors—open up a new paradigm for active stakeholder participation and education. In 2012, DHI and UNEP-DHI Centre embarked on an initiative called Aqua Republica, where participants are expected to develop a virtual world based around a river basin where a limited amount of water needs to be shared between competing users and uses. The aim is to raise awareness of the importance and

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O. Sourina et al. (eds.), *Subconscious Learning via Games and Social Media*,
Gaming Media and Social Effects, DOI 10.1007/978-981-287-408-5_3

interconnectivity of water, as well as educating about how it can be more sustainably managed through integrated water resources management (IWRM).

Aqua Republica combines a game layer with a water allocation model, MIKE HYDRO (DHI 2013), to create an interactive, realistic virtual environment where players play the role of a democratic leader of, what is initially, undeveloped river catchment. The main objective is to sustainably manage the river catchment, so the inhabitants become as materially and spiritually prosperous as they can be. To achieve that, players need to drive the catchment's economy to provide the funds needed for further development and have a steady food supply for a growing population and enough energy and water to maintain both growth and environmental services. Players are engaged and educated about the relationships between developmental actions in a river basin—as well as their consequences. The game layer also consists of a reward system to encourage learning through competition and more positive actions. For example, a player who takes care of the ecosystem while developing the catchment gets a bonus score and gets a rewarding event, while a player who does not will encounter pollution events, will need to spend more resources on cleaning up, and will ultimately receive a lower score. Such game mechanics are designed to engage people and increase their interest in sustainable water resources management.

Different versions of the Aqua Republica game are developed to support different interests. Examples include a version for educating school-age children, a version for stakeholder participation in workshops, and a version for raising awareness within certain sectors or business interests.

1 Introduction

According to the 2012 UN Water Status Report (UNEP 2012a) on the Application of Integrated Approaches to Water Resources Management, 82 % of countries are implementing changes to their water laws for a more integrated approach to water resources management. This probably indicates that there is general consensus on the importance of the issue. However, according to the same report, only 35 % of the countries have sufficient training programs for IWRM—the accepted approach for managing water sustainably. That is a massive gap between the will and the capacity to solve water problems. It is obvious that we need to narrow this gap, but how do we do that?

Capacity-building programs and training programs have been going on for many years, and education is a complex and continuous process; nevertheless, there is a constant push to try to find new ways to make these efforts more efficient, effective, and scalable in order to achieve the desired progress. A major opportunity to accelerate progress is through the utilization of opportunities provided by advances in and dissemination of information and communications technology (ICT).

One of the main upsides of digital communication and information is the accessibility; for example, the ability to communicate socially, organize financial transactions, and keep up to date with the very latest local and international news is becoming more and more commonplace for people on all income levels. One of the main downsides of digital communication is the overabundance of information; for example, consider the number of hits a search engine returns on a simple search, or the amount of online advertisements a typical Internet user may be exposed to during the course of day. At the same time, as more and more information becomes available on the Internet, nothing is ever deleted. We are exposed to these sources at such a high rate that it affects the way our brains process information (Small and Vorgan 2008; Gee 2003a and 2003b). According to Small and Vorgan (2003), daily exposure to high technology—computers, smartphones, video games, and search engines—stimulates brain cell alteration and neurotransmitter release, gradually strengthening new neural pathways in our brains while weakening old ones. Today, every single source of information, be it books and papers, Webpages, television programs, podcasts, YouTube videos, short messages (SMS), Facebook notifications and so on, competes for our attention, and the most interactive and engaging one normally wins.

With this as a backdrop, we now face additional challenges in capacity building; besides having to make it more efficient and scalable and so on, we also need to keep up with communication trends and technology to be able to attract the attention and interests of our target audience.

If we consider where capacity building starts, at school, and think about our own experiences and those of our classmates, we can all easily recall that in general there is a big difference between what motivates students. Typically, children are motivated by activities that they consider to be fun, and often less so with formal activities and associated materials that schools consider of greatest importance (after Stapleton and Taylor 2002, 2003; Stapleton 2004; Shute et al. 2009). A desirable approach is one where the fun activity part is combined with the topics traditionally included in the more formal activities, in order to increase the potential for learning.

Such an approach is applied through serious gaming, and it is being used with success in many different fields ranging, for example, from health care and city planning, to engineering and religion. In this paper, we will take a look at an interactive approach to capacity development with the use of serious games in the field of water and especially so in IWRM.

2 What Is Serious Gaming?

When we encounter a problem, it is always wise to go back to the fundamentals. That leads us to a quote from Confucius, a Chinese philosopher who once said "I hear and I forget. I see and I remember. I do and I understand." The keywords are doing and understanding, but how could we do or practice IWRM?

Imagine a virtual world that mimics the complexity of the real world, in terms of water environments. A virtual world which allows us to test out development plans, test out new regulations, visualize the potential impacts, make mistakes, and as a result learn through personal experience. This is the concept of serious gaming.

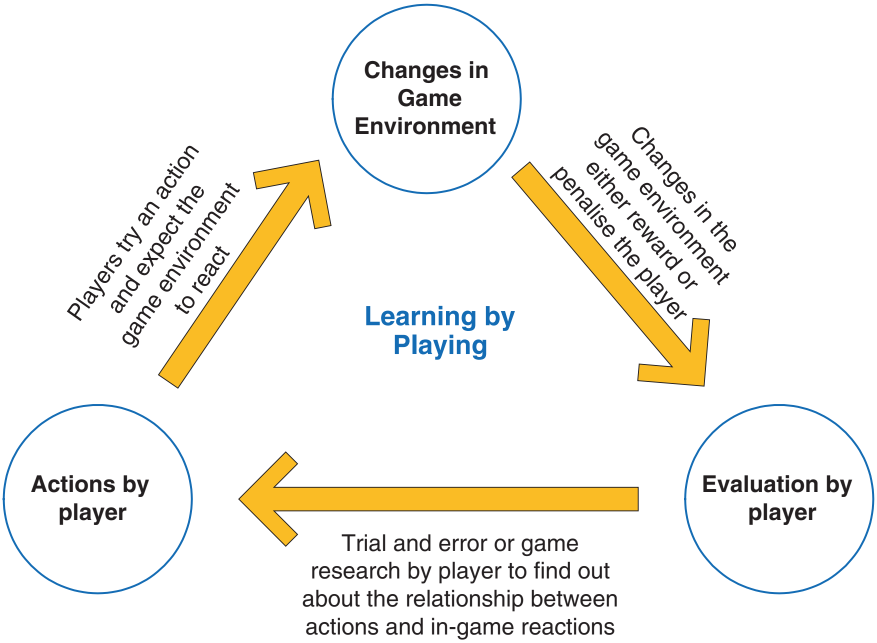

Fig. 1 The cycle of learning by playing

A serious game is a category of games that are designed with the intention to teach rather than for pure entertainment, whereas a casual game is defined here as a game for pure entertainment. However, it does not mean that serious games cannot be entertaining. Serious games that are well designed yield "meaningful play," a condition very much like learning. According to Salen and Zimmerman (2004), meaningful play is when the relationships between actions and outcomes in a game are both discernible and integrated in the larger context of the game. Serious games also shift the focus of control in learning from the teacher to the player and create an environment that stimulates learning, often resulting in an increase in self-learning and knowledge retention (Fig. 1).

While learning can occur within a casual game, it is a by-product rather than the intended outcome of the gameplay. Both types of games vary in different forms of genres, platforms, and story lines, but a good game, whether it is a serious game or a casual game, has enough challenges and rewards, as well as entertainment value to keep players' attention.

When describing the distinct difference in the two types of a game, it holds true that the devil is in the detail. A serious game is embedded in a realistic context, whereas a casual game may use a realistic context as a way to create a more believable game. This becomes clearer as we look at some of the key components of how games work on low level.

Games are interactive, which is what makes them different from traditional media. However, interactivity itself is meaningless without a context. Opening or closing a door is interactivity, you interact with the door, but whether or not it makes sense requires that there is something we are striving toward—a goal. If we want to conserve heat by not letting cold air into the house, the interaction of closing the door is suddenly meaningful.

Games thus are interactive and have a goal. This is true for all types of games. The last part to making a game is to combine the purposeful interaction with opposition. Opposition forces the player to make choices; the type of choice that the player has to make is often part of deciding which genre label is put on a game. Shooting games require quick twitch actions, and many of the choices made are almost subconscious, duck, jump, or sprint to the next piece of cover and such. Turn-based strategy games involve choice based on the analysis of the current state of game and the range of possible actions based on current resources and an understanding of how current actions change the game state—for example, chess.

Games also have a structure. In a typical board game, the structure would be the rules which you play by. In a digital game, the structure defines what you can do within the game and how the feedback loops work. The structure defines which actions you can take in order to overcome the opposition and reach your goal.

Every game also conveys information, which is passed on to the player. The information is needed for the player to make choices; without information, the choices will be random and that will quickly grow boring; since then, it is not you overcoming the opposition; then, you might as well have flipped a coin in the beginning to determine the outcome.

The above is still part of games whether they are considered serious or casual, but we are getting closer to the part where they branch. The nature of the games being a visual interactive environment with its own structure and feedback mechanisms also means that games "create their own meaning" also called "endogenous meaning" in an article by Costikyan (2002). For example, consider that a big white box with a red cross on it means that one gets 100 points for each hit as part of a shooting game. This gameplay logic makes sense within the game, but is not a lesson that can be readily transferred and applied in the real world. This is where serious games tend to stand apart.

The meaning created in a serious game and the verbiage used to describe it should have a relationship to the subject matter it is trying learn the player about. So that if a player is asked to describe what happened in the game, this description will have roots in real life. This is achieved by making the structure, goals, and information received by the player through play related to the topic at hand.

3 About Aqua Republica

Aqua Republica is a DHI and UNEP-DHI Centre initiative that focuses on the development and promotion of a not-for-profit serious game in collaboration with a number of partners. The rationale for producing the game is to promote sustainable water resources management by sharing knowledge, raising awareness, and building capacity in some of the most critical issues in water resources management through serious gaming. This is achieved through a computer-generated virtual environment called, "Aqua Republica" where participants can experience making decisions in managing a catchment in an interactive and engaging way, and in doing so learn about the importance and interconnectivity of water and its uses, as well as it can be sustainably managed. While the world of Aqua Republica is fictitious, the challenges of sustainably managing a limited supply of water resources in a situation of growing demand between multiple users and uses are very much based on real-life scenarios.

The Aqua Republica game is designed to be a powerful teaching tool, which uses a reward system to encourage learning and desirable behavior. It is designed to engage people and increase both their knowledge and their interest in water-related issues. The ambition is to continuously develop Aqua Republica in multiple versions which have both broad and very specific appeal to a wide range of people and contexts.

The game goal in Aqua Republica is to achieve the highest score possible. This is achieved by employing a strategy which seeks to balance water consumption between different water users and uses, while caring for freshwater ecosystems which serve as sources of supply. The game, including the logic behind it, is built upon an engine that realistically simulates the flow of water in a catchment. This engine is used to support feedback to the player. For example, players are alerted if water use starts to become out of balance with demands or if supply is threatened. Players are also encouraged and guided toward appropriate types of remedial action.

Different versions of the game are developed to support different interests, for example, a version for educating school-age children, a version for a stakeholder participation workshop, and a version for raising awareness within certain sectors or business interests.

The following sections of the paper break down the game into a virtual environment and a learning environment and explain in more detail how they support learning.

4 Virtual Environment

The core of Aqua Republica revolves around the virtual environment; this virtual environment tries to simulate a simplified version of the real world. The virtual environment consists of 2 layers—a water allocation-and-hydrology model-based layer and a game layer which uses the results of the model and links it to social, economic, and environmental factors.

The water allocation and hydrology model is powered by MIKE HYDRO by DHI, while the game layer has been developed by a team of water experts. MIKE HYDRO's main application in the real world is to provide solutions to water allocation and water shortage problems, improving and optimizing reservoir and hydropower operations, exploring conjunctive use of groundwater and surface water, evaluating and improving irrigation performance, solving multicriteria

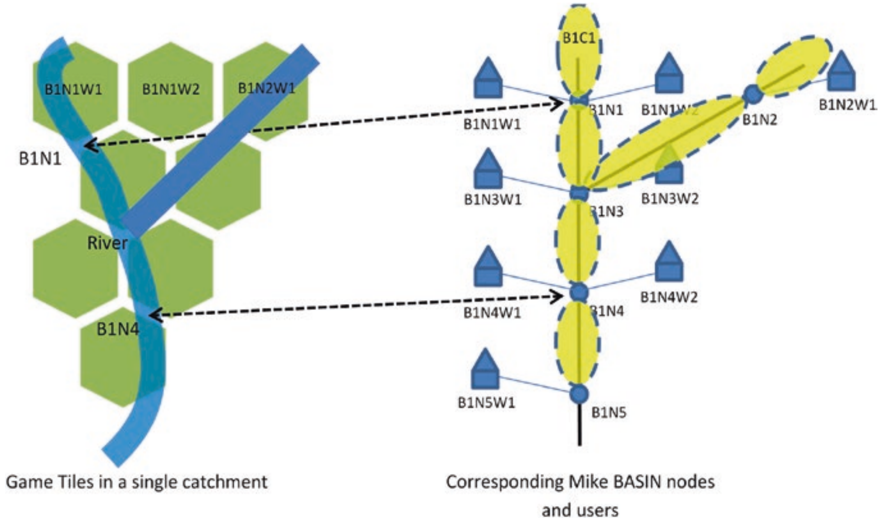

Fig. 2 A schematic view of how a map tile in Aqua Republica (*left*) links up to a node in the corresponding MIKE HYDRO basin model (*right*)

optimization problems, and establishing cost-effective measures for water quality compliance. The concept of linking up the numerical model is simple; the game map is linked dynamically as an input to the numerical model, and any actions on the game will affect the water use of each node in the numerical model (Fig. 2).

Using MIKE HYDRO as the back-end model to calculate water allocation and hydrology provides a lot of benefits:

- It allows us to use the following information in a game, such as
  - Digital elevation model (DEM) of the area
  - Shape files of the river network
  - Delimitation of the subcatchments
  - Runoff data
  - Evaporation losses, level–area–volume curve, bottom level, top of dead storage dam crest elevation, and minimum and maximum release of reservoirs
- It allows us to use realistic water demands for various types of water users or buildings in the game (e.g., crops, irrigation, and various industries)
- It gives us an accurate representation of how water is interacting in a catchment (e.g., upstream and downstream relationships)

The game layer uses the results from MIKE BASIN and affects the social–economic factors in the game. Figure 3 summarizes the interactions in the game that makes up the game layer (Fig. 4).

The game layer consists of several indicators. In this example, the focus is on population, funds, food, energy, ecosystem state, and water. Every indicator can be linked to one or many different structures like the following:

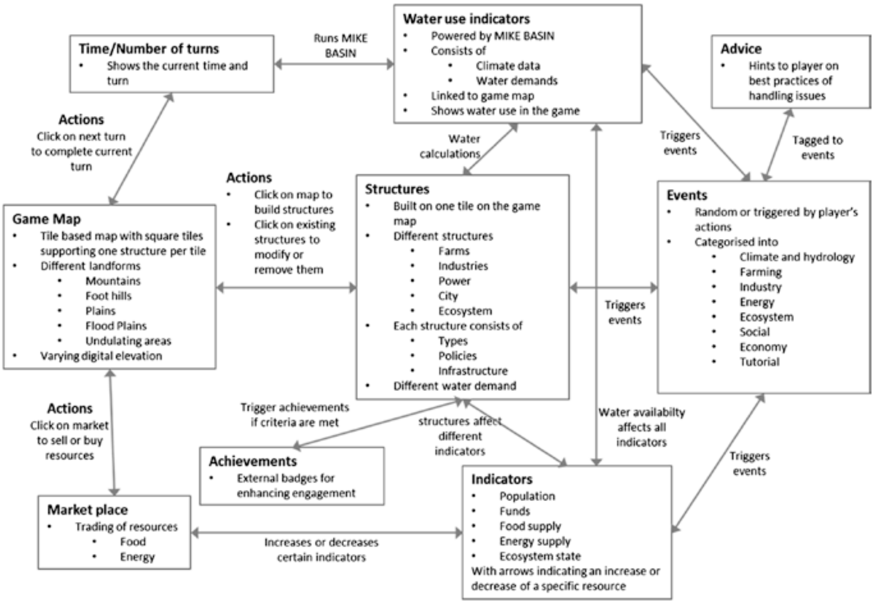

Fig. 3 Game interactions in Aqua Republica that constitutes the game layer. This game layer uses results from MIKE HYDRO basin to process socioeconomic factors

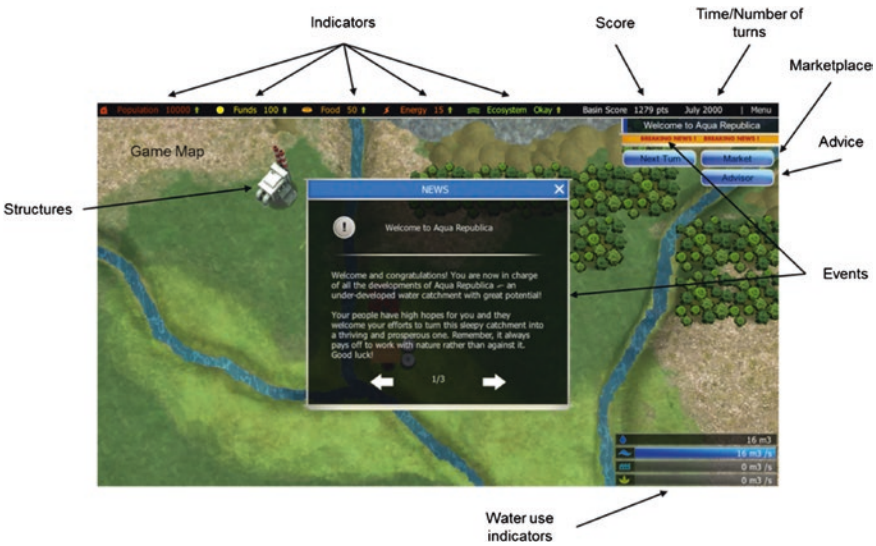

Fig. 4 Example game features of Aqua Republica

- Population
  - Each city in Aqua Republica houses a part of the population, and the bigger the city, the higher the rate of population growth
  - Every city also provides a small amount of jobs
  - Population in Aqua Republica consumes water, food, and energy
  - Population requires jobs and also has an affinity to good ecosystem state

- Funds
  - Funds are needed to build new structures or enforce policies within structures
  - Funds come from employed population

Cities provide a small amount of jobs
Farms provide a small amount of jobs
Industries provide a bigger amount of jobs

  - Funds can also come from trading food or energy in the market place

- Food
  - Food is needed by the population to survive
  - Food is produced from farms. In Aqua Republica, the people have no real preference in the various crops

Different crops in the farms, however, provide different amount of food, use different amount of water, and impact the environment differently

  - Food can also be purchased from the market place

- Energy
  - Energy is needed to power all the buildings in Aqua Republica, except for ecosystems
  - Energy is produced from power plants

Coal
Biofuel
Nuclear
Hydropower
Different power plants provide different amount of energy, use different amount of water for cooling, and impact the environment in different ways

- Ecosystem state
- Energy can also be purchased in the market place
  - Ecosystems require a minimum environmental flow of water
  - Ecosystems provide many different services to the catchment

- Water
  - Water is required for all structures including ecosystems to function
  - Water in Aqua Republica comes from an upstream source, local rainfall, as well as local groundwater aquifers
  - Water also flows to a downstream neighbor
  - There are only two types of water quality in Aqua Republica—clean and polluted water

Polluted water affects the productivity of all structures

The combination of the numerical model and the game layer creates a sandbox to practice making decisions. With all the underlying logic mapped out behind the scene, the player can apply theories on integrated water management, visualize consequences, and learn both by taking the right actions and by making mistakes in the game.

5 Learning Environment

Aqua Republica is a learning tool. It is not meant to simulate actual river basin management in a real catchment. However, the game can be used by players to learn about the conflicts and trade-offs that exist in a real catchment by experiencing it through meaningful play. After playing the game, players better understand the needs and perspectives of all the stakeholders involved in IWRM as well as the role and value that ecosystems perform and provide.

The focus of control of learning in Aqua Republica shifts from the teacher to the student. This helps create a more personal learning environment where players feel in control of their learning experiences. In addition to event notifications and strategy advice, a reward system is used to encourage certain behavior through positive reinforcements when the player does something right, and negative reinforcements when the player does the opposite.

The key objectives of the game are inspired by UNEP's ecosystem approach to IWRM, highlighting the importance of ecosystems and services that they provide (e.g., food security, freshwater supply, and disaster risk reduction). The game also shows that cooperation within a basin does not come automatically and needs to be both established and maintained.

Figure 5 shows the key ecosystem services that are used to inspire the game.

The current game platform is a turn-based strategy game where a player plays through 12 turns which equates to approximately 20 years. The player can spend as much time as desired before making a move and committing to it by choosing to press next turn. As such, there is no time pressure on the player to take a move, thus allowing discussions and deliberations before ending the turn and moving on to the next time step.

At the beginning of each new turn, the player will be presented with a news screen which reports on different events. These events inform the player of changes in the game environment, as a result of which actions the player took. The player can then evaluate the new state of the game and take informed actions.

The first 3 turns are part of a tutorial phase, where information about the entire gameplay is presented. During this phase, the game informs the player on which actions are needed to fix immediate needs at the start of the game. This helps introduce the player to the interface of the game and guides the player on what possible actions to take. However, the player can choose to take other actions which may result in other consequences. After the first 3 turns have passed, the player has taken all basic actions and been able to reflect upon them.

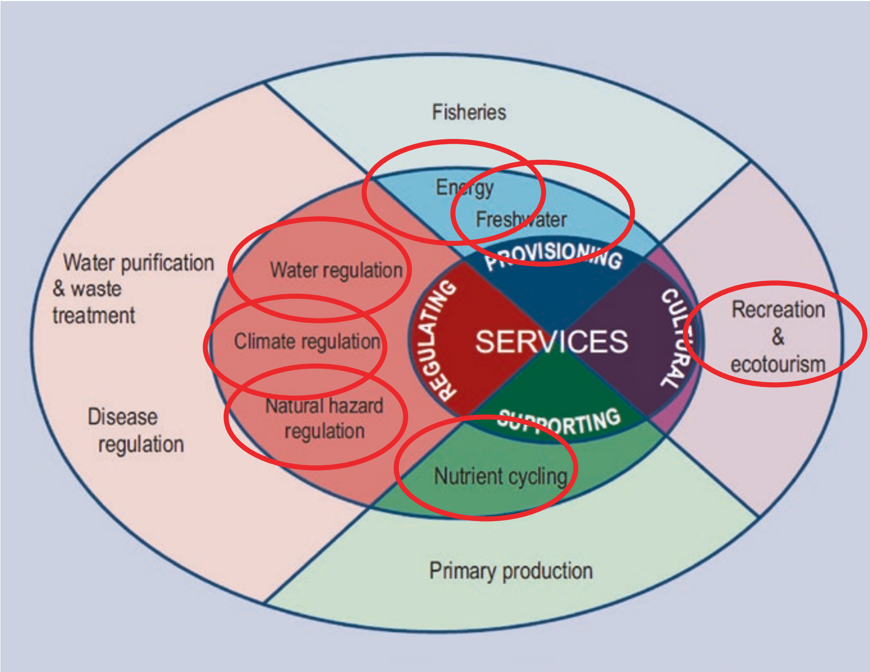

Fig. 5 Ecosystem services represented in Aqua Republica, *Source* UNEP ecosystem management program (UNEP 2012b)

Events in the game are classified into random and triggered events and are categorized as follows:

1. Tutorial events help guide the player to understand the mechanics of the game as well as the different components of the virtual world.
2. Climate- and hydrology-related events, which emulate the weather system and trans-boundary-related issues as well as disasters such as flooding and droughts.
3. Farming-related events highlight farming-related issues, such as conflicts in land use and conflicts in water allocation, pollution and so on.
4. Industry-related events highlight industry-related issues, such as conflicts in land use and conflicts in water allocation and pollution.
5. Energy-related events highlight the issues of energy, their use of water, and their impacts on the environment.
6. Ecosystem-related events are mainly events which highlight the benefits of ecosystem services.
7. Social or population-related events highlight the views of the population in the game and the issues that a city has in terms of water and the environment.
8. Economy-related events affect the economy of the game; they also include changes in the economic rules of trading and how money is earned in the game, reflecting the flux of a global market.

Fig. 6 Example scorecard and score breakdown in Aqua Republica

6 Reward and Evaluation System

Events in Aqua Republica are also an important part of evaluating a player's performance in the game. As events can be triggered by the actions of the players, actions which are in line with the principles of IWRM will trigger positive events. This rewards the player visually, as the event will encourage the player with a virtual "pat on the back"; it may also cause the game to display additional graphical rewards. The positive events moreover give extra points as well as extra funds or food in the game.

On the other hand, when the player's actions are not desirable, the game will trigger negative events. This will display events which will discourage the player to continue with the actions by penalizing the player with reprimanding tones in the events as well as deduction in scores, and resources in the game such as food, energy, funds, and state of the environment.

This means that the score at the end of the game gives an indication of how well the actions of the player are in accordance with the good water resources management. A scorecard can be used to summarize the different score components both during gameplay and at the end of the game.

As shown in Fig. 6, the score of the game can be based on a basin score consisting of the following:

- Population score shows the general well-being of the citizens of Aqua Republica. It is further broken down into 4 parts:
  - Density: The citizens will generally be contented if there is a good living space, so if population is increasing, there should be more cities in the game.
  - Job situation: The citizens will be contented if there are enough jobs in the game. Jobs are created by cities, farms, and industries.
  - Food Surplus: The citizens require food.

  - Steady power supply: The citizens also require energy.
- Production score shows the economy and food production of Aqua Republica.
- Ecosystem score shows the state of the environment of Aqua Republica. There are 2 components to this score—the rating of the ecosystem which reflects how pristine or damaged the ecosystems are and the water use in the game.
- Sustainability score shows how sustainable the developments are in the game. This is done by running the numerical model 3 time steps into the future and getting the score based on the future results.
- Achievement bonuses are extra score awarded to the player for outstanding feats of strength in the game. Some examples of achievements are Green Peace Award, which occurs when the player does not encounter any pollution event throughout the game; another example is Water Manager Award, which occurs when the player does not encounter any water shortage events in the game.

7 Gameplay and Applications

Aqua Republica is designed to be used broadly, and hence, there is no one version of the game that can fit into all the scopes of IWRM. To overcome this problem, Aqua Republica is spilt into core and unique versions.

The core version of Aqua Republica is a framework of game features and game modules which can be assembled into various unique versions. A unique version of the game can be a change of numerical model data, landscape of the game map, and having a different set of events and advice. A unique version is also more focused on a particular set of learning goals.

As noted by Egenfeldt-Nielsen (2007), "Serious games should not be seen as a standalone experience but optimally in interplay with other teaching tools. The serious games field has an even clearer rejection of the fallacy that an instructor can easily be replaced. The instructor is crucial for ensuring reflection and guidance during the learning experience. Obviously, you will still learn without an instructor, but you risk losing focus and effectiveness, as you can't replace the sensitiveness a good instructor can apply to progress learners."

There are many ways of using Aqua Republica, such as a stand-alone tool to promote IWRM or using it as a supplement to existing training programs or workshops for more focused learning and effectiveness. Depending on the uses, there are also different ways to play the game.

Table 1 lists the possible applications of Aqua Republica. Each application can be used by itself or can be used in various combinations.

For a stand-alone tool, you play the role of a water manager and you are in charge of all the developments of a part of a river basin with multiple stakeholders. Your area initially contains a river, a small urban area that includes some businesses and light industry, a few farms and a small power station. Your aim is to create prosperous living conditions for the population in a healthy and sustainably managed environment. As time moves on, drivers such as population growth, climate change, and trans-boundary developments force you to adapt to survive and thrive, for example, you may need to decide to clear a forest area to open up

Table 1 Different applications of Aqua Republica

Applications of Aqua Republica	Purpose
As a stand-alone Web-based game without any facilitators	Raise awareness of water issues Build capacity on an individual level
As part of hands-on exercises in a workshop of training course with a facilitator	Build capacity on an individual and organization level Engage participants' interest and increase discussions
As a competition between participants in a workshop or training course	Monitor and track learning progress Engage participants' interest and increase discussions
As part of evaluation in a workshop or training course with a facilitator	Monitor and track learning progress
As a tool to facilitate decision-making discussions in workshops with a facilitator	Raise awareness of water issues Build capacity on individual and organization and enabling environment level Engage participants' interest and increase discussions by visualizing consequences of various decisions

land to expand industry or an upstream neighbor uses too much water and you need to start to negotiate and react. However, developments are costly, take time to implement, use water, and impact the environment. How would you balance all the developmental needs while taking care of the environment?

Other uses of the game are only limited by your imagination; you can play with a group of people, each person representing a different stakeholder role, while one person represents the water manager that is in charge of Aqua Republica. Before deciding on which building to construct in the game, go through a series of discussions, do the actual construction in the game, and visualize the impacts. A follow-up discussion can be done after each turn to evaluate the previous decisions and discuss the next possible moves. This stimulates an actual process of IWRM.

Another way to play the game in a group is to be more open-ended, for example, if the group of participants are more homogeneous and come from one specific group of stakeholders. Before any development in the game, a discussion can be held within the group of participants; the discussion can be driven by the events from the game. In this case, when the group of participants are more inclined to farming developments, the game will present more farming-related issues and give the participants a bigger picture perspective of water and farming as well as the connectivity of other industries.

8 UNEP-DHI Eco Challenge

One example of the application of Aqua Republica is through an online gaming competition called the UNEP-DHI Eco Challenge. The competition was first held in 2013 where students from high schools (age between 13 and 16) were encouraged to sign up to the competition. The competition was represented by 33 teams from schools in Singapore, Hong Kong, India, and Thailand.

These teams consisted of three students, and each team was accompanied by a teacher. The competition lasted for 3 days, and students were told to play the game online, and their aim was to achieve the highest score possible in the game. There were two different setups in the competition, each depending on the preference of the school. The first setup was to allow the students to play the game at their own time, and the teacher will act as a guide whenever the students needed help. The second setup was to get all the students to play the game in a common space, such as the school's computer laboratory, while the teachers function only as guides.

When the students started the competition, their scores were universally low. However, as the competition progressed and they had the opportunity to gain greater experience in playing the game, the scores achieved were progressively higher and higher.

The teams with the top ten scores were also from the second setup where the students were gathered in a common space and where the teachers were readily available to give advice on appropriate courses of action.

The increase in scores over the duration of the competition indicated that the students understood the mechanics of the game and were exploring different gameplay in an effort to maximize their scores. The game was designed such that the higher scores obtained meant a better water management has been achieved in the game. The scores achieved also showed that players had generally done well in terms of maintaining a good ecosystem state.

In order to gain a clearer picture of the educational value of the game, both teachers and students were asked to reflect on the learning experience over the three days. The reflections showed that the game and competition increased the interest of the students in topics such as water management and pollution, and as a result, they asked the teachers for more information about such topics and were generally eager to consult additional information sources such as educational books and the Internet.

The following quotes are two examples of the students' reflections:

> "The game relies on the fact of being able to manage our water resources well enough so as to able to score a high point. When I first played the game, I thought getting a score relied on the fact that by building lots of industries, we were able to obtain a really good score as more industries = more income = more points. Oh how wrong was I. After countless of tries just building industries and not realising that my ecosystem was steadily decreasing, I took some time to think about the matter and realised what I did wrong."—Matthew Tang, age 14

> "I have learnt from Aqua Republica, not only knowledge beyond our current textbook syllabus about water and land use, but also many life skills such as teamwork and perseverance. For example, we were already one day behind our competitors when we started. At that time, the highest score we could get was around 1000 points. The highest score at that time was more than 20 times more than us. There were times where I thought of giving up as I thought that getting scores like that was impossible and also as we have a limited time of 1–2 days left. But, I was resilient and did not give up; instead, I took down notes of the teachers' advices and also took down our steps to see whether there was any way to improve on it. We persevered and finally managed to find the winning solution and achieved almost the same score as the top scores."—Brian Kang, age 14

This exercise supported the notion that serious games can have a positive impact on education, especially in water, and even over a short period of three days, students have shown to be more interested in the subject and have gained knowledge through self-learning.

9 Discussions

Serious gaming in the water sector is an interesting and innovative way to enhance capacity building. Tabletop games and role-playing games have been used previously in various capacity-building exercises within the water sector (for example, the IUCN's BRIDGE project), and they have been documented to increase the engagement of participants in workshops and training courses by breaking down the barriers of communication and therefore create a better learning environment.

Digital and Web-based serious games on the other hand are a new breed of serious games in the water sector. While it is important not to be dismissive of more traditional game types, there are definitely potential comparative benefits in using digital serious games in terms of scalability, using of real-life data to create more awareness of local issues (e.g., both in terms of hydrology and in terms of people's behavior) and the ease of running the game online. Digital games with scoring and achievement components are also able to track players' progress if the games are used often enough. There is also room for better data analytics to be included in serious games for educators to better monitor the progress of students as well as for students to understand where there are gaps in their knowledge.

However, digital games may fall short when it comes to building capacity in more rural areas where Internet connectivity is low or areas where computer illiteracy is high. The approach is then to use the appropriate tools to build capacity for the appropriate target groups. It is also worthwhile to consider having both tabletop and digital games with the same learning goals and be able to choose the most appropriate tool for different circumstances and different target groups.

Acknowledgments The unique version presented in this paper is a project with a consortium of partners—DHI, UNEP-DHI Centre for Water and Environment, United Nations Environment Programme (UNEP), Ministry of Foreign Affairs Denmark (Danida), and Serious Games Interactive (SGI). The authors would like to acknowledge their contributions to the project.

References

Costikyan, G. (2002). I have no words & I must design: Toward a critical vocabulary for games. In: Frans Maeyrae (Ed.), *Proceedings of the CDGC Conference in Studies in Information Sciences* (pp. 9–33). Tampere: Tampere University Press.

DHI. (2013). MIKE HYDRO basin—integrated river basin planning. Accessed July 1, 2013. http://www.mikebydhi.com/Products/WaterResources/MIKEHYDROBasin.aspx.

Egenfeldt-Nielsen, S. (2007). Experiential eLearning: An ID model for serious games. Accessed Jul 3, 2013. http://www.egenfeldt.eu/papers/overview_serious_games.pdf.

Gee, J. P. (2003a). High score education: Games, not school, are teaching kids to think. Accessed Jul 5, 2013. http://www.wired.com/wired/archive/11.05/view.html?pg=1.

Gee, J. P. (2003b). *What video games have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Salen, K., & Zimmermn, E. (2004). *Rules of play: Game design fundamentals*. Cambridge: The MIT Press.

Shute, V. J., Ventura, M., Bauer, M. I,, & Zapata-Rivera, D. (2009). *Melding the Power of serious games and embedded assessment to monitor and foster learning*, Chapter 18, Serious games: Mechanisms and effects (pp. 295–321).

Small, G., & Vorgan, G. (2008). *iBrain: Surviving the technological alteration of the modern mind*. New York: Harper Collins Publishers.

Stapleton, A. (2004). *Serious games: Serious opportunities*. Paper presented at the Australian Game Developers' Conference, Academic Summit, Melbourne. Dec 2, 2004.

Stapleton, A. J., & Taylor, P. C. (2002). *Physics and playstation too: Learning physics with computer games*. In: Proceedings of the 15th Biennial Congress Australian Institute of Physics. NSW: Darling Harbour, July 8–11, 2002.

Stapleton, A. J., & Taylor, P. C. (2003). *Why videogames are cool & school sucks*! Paper presented at the Annual Australian Game Developers Conference. Melbourne, Nov 20–23, 2003.

UNEP. (2012a). *The UN-water status report on the application of integrated approaches to water resources management*. United Nations Environment Programme.

UNEP. (2012b). *Ecosystem management programme: A new approach to sustainability*. Accessed Feb 2, 2012. http://www.unep.org/themes/freshwater/pdf/ecosystemmanagementprogramme.pdf.

The Future of Immersive Technologies and Serious Games

David Wortley

Abstract This presentation seeks to explore likely developments in immersive technologies (defined as those technologies and applications which so immerse us that we choose to spend our discretionary time, attention, and income on them) and serious games (defined as the use of video game technologies and applications for non-entertainment purposes). It argues that immersive technologies, serious games and "gamification" are likely to play a vital role in addressing some of the most important challenges faced by business and society in the twenty-first century. This paper examines some of the disruptive changes that have taken place in the last 50 years as a result of digital technologies and their impact on our daily lives and illustrates the potential of these technologies to shape a more sustainable future.

Keywords Gamification · Immersive technologies · Serious games · Global challenges

1 Introduction and Background

Ever since the video game "America's Army" was launched as a tool to support the recruitment of young people into the US Military, the term "serious games" has gained traction and acceptance as an important use of "entertainment technologies" for serious purposes such as training, simulation, assessment and behavioural change across a wide range of sectors. Although the technologies used were new and emerging rapidly, the concept of using gameplay to train, educate and motivate is as old as humankind itself.

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O. Sourina et al. (eds.), *Subconscious Learning via Games and Social Media*, Gaming Media and Social Effects, DOI 10.1007/978-981-287-408-5_4

Today, however, these technologies that we are increasingly choosing to spend our time, attention and money on are growing in importance as an increasingly necessary tool for engaging us and creating a platform for building sustainable relationships.

2 The World Circa 1950

In the aftermath of World War 2, the generation of so-called baby boomers entered a world that was shaped by the Industrial Revolution and the power of machines to augment the strength, speed and efficiency of human beings. In this world, there were no computers and very few cars, televisions or telephones in the majority of households. Society and business were structured on a hierarchical basis in which "knowledge was power" and daily life was quite structured such that:

- Teachers transferred knowledge
- We knew all our neighbours
- We rarely travelled outside our community
- Banks were banks, Grocers were grocers
- We built a career in the same company
- We dated and married within our community
- Individual choice and power was limited

Children's games shaped our personalities, interests and perceptions of our role (Fig. 1).

Games and simulations had always played a very important role in our development as children, stimulating our interests, helping us to understand our capabilities and shaping our relationships with others. In this society, knowledge and understanding was passed down from those whose years of experience and training empowered them with the necessary wisdom and skills. The only "on-demand" access to information was found in libraries, so self-directed learning opportunities were extremely limited.

Education and training in this era was almost entirely based on physical classrooms where knowledge professionals such as teachers and trainers used "chalk and talk" methods to transfer their knowledge and skills with assessment of knowledge based on formal exams and tests which provided the certification and status demanded for career progression.

Knowledge professionals and specialists were predominantly the sole providers of service in all sectors of society including education, health, engineering and law, and career progression was seen as a process that often took place within a single company or organisation. The whole structure of society in work and play was based on the development of long-term relationships, and it was very difficult to cross boundaries between disciplines and professions.

Fig. 1 Children's games simulating adult roles—(http://image.dhgate.com/albu_857696374_00-1.0x0/2014-girl-children-039-s-toys-simulation.jpg)

3 The Impact of Digital Technologies

It was not until the 1980s that digital technologies began to have an impact on business and society. By this time, minicomputers had begun to appear in larger organisations, largely to automate and improve administration functions and making organisations more cost-efficient. It was around this period that digital communications technologies and affordable data modems began to create opportunities to provide new types of services and the first signs of the disruptive impact of technology were seen (Fig. 2).

Like other disruptive communications technologies throughout history, the digital communications technologies made it possible for knowledge and information to be more quickly, accurately and efficiently disseminated to larger populations.

Fig. 2 The IBM 5120 computer circa 1982—(http://oldcomputers.net/ibm5120.html)

Just as the impact of the printing press centuries before had spread learning, so the growing numbers of computers and devices capable of storing and communicating data and information began to be applied to training and education. The early desktop computers with their limited storage capacity and monochrome displays were used to store and print text documents, and as early as 1984, the first IBM desktop computers were being used to send personalised Mailmerge invitations and information sheets via telex machines.

As the potential of desktop computers began to be developed through higher capacity storage devices, colour displays and faster digital communications devices, other consumer technologies emerged alongside commercial computing but targeted at entertainment. Arcade game machines such as space invaders helped to raise awareness of and spawn home computers capable of both entertaining and educating, even providing opportunities for individuals to begin to learn how to create their own programs. The early days of computer-based training (CBT) combined digital content with quizzes and tests that could develop learning in a very linear fashion and track learning outcomes, and so the early learning management systems were born and used to plan and manage structured formal training programs (Fig. 3).

As the capabilities of desktop computers grew and became more accessible through graphical user interfaces (GUIs), new input devices such as the computer mouse, search engines such as Alta Vista and the invention of hypertext, the learning and training capabilities of computers began to shift from structured linear

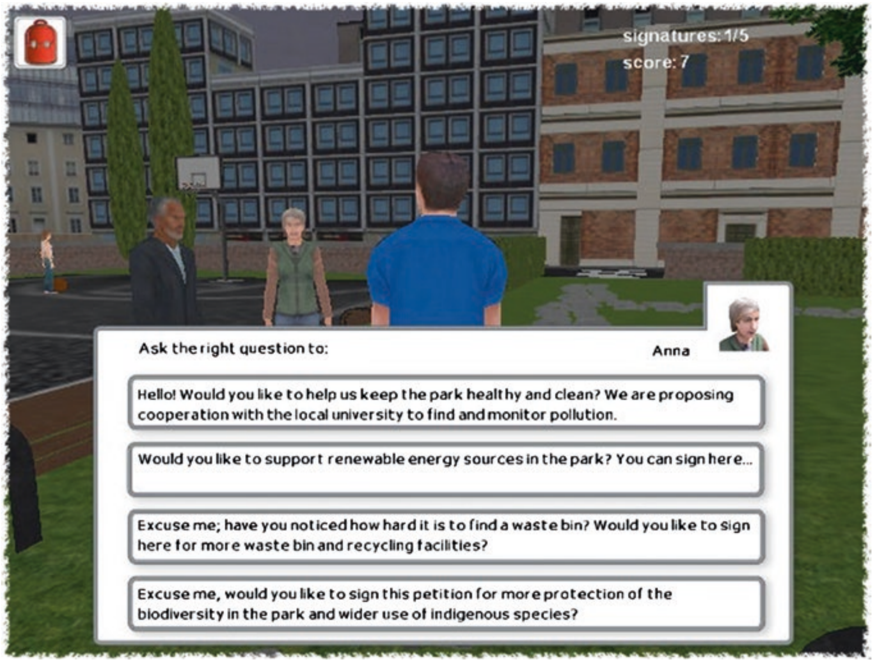

Fig. 3 ASPIS serious game for public space planning by imaginary (www.i-maginary.it)

processes towards nonlinear self-directed processes based on knowledge creation and discovery rather than existing knowledge dissemination. With the invention of the Internet in 1989, an irreversible process had begun that empowered learners in previously unimagined ways that continue to impact and shape today's society.

4 The Generation Y Age

The invention of the Internet in 1989 is generally described as the starting point for a whole new generation of human beings known as "digital natives" because they were born into a world unlike any previous era because of the availability of and access to digital communications technologies that could empower and develop their capabilities in new ways that were less dependent on knowledge professionals such as teachers and doctors (Fig. 4). Motivated, challenged and inspired by these technologies which quickly became part of everyday life for young people, the structure of society began to change slowly at first but with growing momentum to the situation today in which:

- Teachers are coaches and mentors
- We know none of our neighbours

Fig. 4 Digital native multitasking—(http://brauertraining.com/images/blog/_blogMain/dgital_native.jpg)

- We travel and live outside our community
- Record companies become airlines, Grocers become banks
- We change jobs and companies often
- We date via the Internet and do not marry
- Individual choice and power is unlimited

5 The Impact of Web 2.0

With the arrival of the twenty-first century, a new phenomenon emerged—Web 20. The usability of and ubiquitous access to computers and other digital communications devices such as mobile phones and games consoles created a demand amongst a growing population of users not only to learn and develop in self-directed ways that did not depend on traditional knowledge professionals, but also to create and share knowledge, ideas and opinions with others. Web 2.0 refers to the tools which enable ordinary users to be able to create and publish rich multimedia content with a global audience at an affordable cost through websites and other digital communications channels (Fig. 5).

Web 2.0 has made it possible for individuals with great ideas and ambitions to compete with and/or impact far better financially resourced organisations in almost every sector of society, creating what is often called the "asymmetric society". This is particularly evident in military and security sectors where asymmetric warfare is creating real challenges for security forces all over the world, but the phenomenon exists in almost every other sector because of the empowering nature of these technologies.

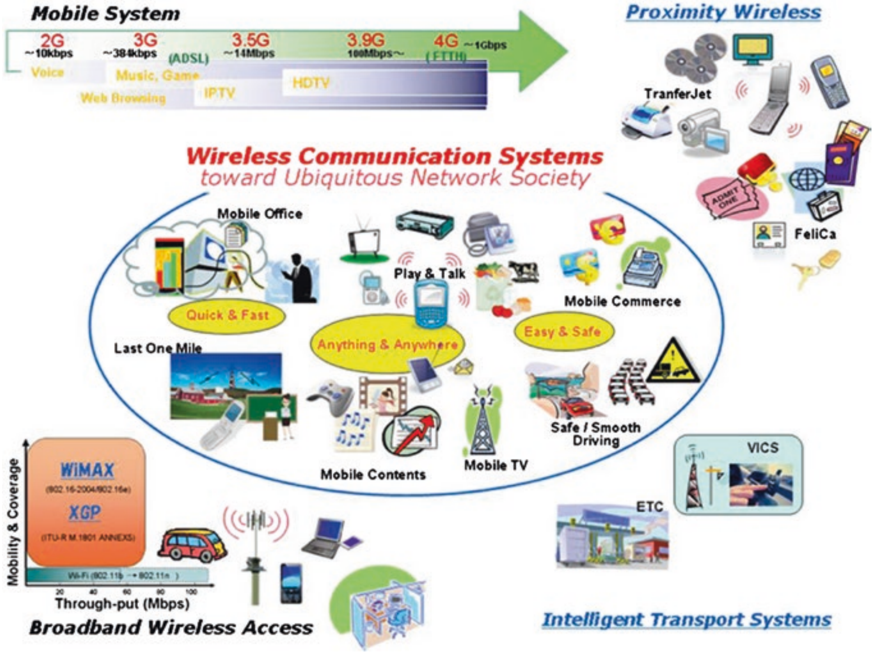

Fig. 5 Internet of Things schematic sensor network—(http://www.arib.or.jp/english/html/wireless/images/watuns.jpg)

6 The Attention Economy

With the exponentially increasing amount of content being published every day, two new phenomena became apparent—information overload and the attention economy. Business and social lives increasingly became dictated by the volumes of information demanding attention from all forms of media. Volume and diversity of information creates both challenges and opportunities for both those publishing information and those whose lives depend on acting on information. Anyone, from whatever sector, needing to influence or develop other human beings, whether to educate them or prompt them into action, faced increasing levels of competition for attention, which requires strategies to engage interest (Fig. 6).

One of the ways of engaging attention is the quality or "richness" of the experience through the use of high-fidelity graphics and media designed to create impact that differentiates the content from competing sources. The games industry continued to push back the frontiers of technology to provide increasing levels of realism which can be very important in certain types of application where understanding, reaction, engagement and trust can all be influenced by the richness of the experience.

The games industry was also the source of another strategic innovation that had an impact on the competitiveness of content and has driven the development of

Fig. 6 Triage trainer screenshot—(www.trusim.com)

new forms of human–computer interface that either help to make the technology more accessible and easy to use or create new forms of interaction with technology that are engaging. Examples such as the Nintendo Wii and Microsoft Kinect not only extend the market potential of games to wider target audiences but also create new applications outside the world of entertainment and devices such as Neurosky which uses brainwaves to control the input to technology has introduced new genres of application which can engage and immerse users.

7 Personalisation and Technology

The final development that has been at least partly driven by the challenges of the attention economy is the increasing use of technologies such as artificial intelligence to personalise user experiences and engage our discretionary time, attention and income by either empowering users to create and modify their own information dissemination channels or filtering the vast amounts of information offered to users so that they are as relevant and accurately targeted to the personal characteristics of the user.

The ability of users to personalise their own publishing channels and deliver content and shared experiences to a global audience is reflected in the success of social networks such as Facebook, whilst the personalisation and filtering of information based on user profiles and preferences is a feature of dominant market players such as Google and Amazon, both of whom have sufficiently large user bases to use "wisdom of the crowd" artificial intelligence to techniques to deliver effective services that benefit from developing a personal relationship with the characteristics of their users.

8 The Empowered Prosumer and the Networked Society

The net result of all these developments in technologies and practices that engage time, attention and income is a global society in which consumers of products, services and knowledge are simultaneously also producers of products, services and knowledge. We all now have the tools to be prosumers, and this empowerment of individual citizens with greater control over their lives and less dependence on knowledge professionals to provide services has had profound effects on both business and society.

One of the effects is the so-called disintermediation that manifests itself in the cutting out of intermediaries in the supply chain which leads to less layers in hierarchical organisation structures and a shift from hierarchical organisational structures to networked or peer to peer networked structures. In a very real sense, today's society is paradoxically both the most connected (in the sense of the ability to deal direct with more entities anywhere in the world) and the least connected (in the sense of the strength, longevity and sustainability of the relationships we have with those we are connected to).

9 Today's Global Challenges

The empowerment provided by today's converging and fast-moving technologies has had many positive effects on society, but it is also arguably the source of many serious global challenges in the areas of education, health, environment and security. Because we have access to global knowledge on a 24/7 on demand basis through multiple devices, we have a greater degree of independence than previous generations. The added control over our own lives also gives us the power to affect the lives of others elsewhere on the planet without bearing any responsibility for the consequences of our actions. The greater freedom of choice we have in our daily lives has implications for the rest of society as well as ourselves, and some of the looming societal challenges may well force us to rethink how we can strengthen society by the strategic use of the same technologies that are fuelling these changes (Fig. 7).

As a specific example, the improvements in the standard of living in the developed world and the availability and variety of food, shelter and health care mean that life expectancy is increasing, but there is a growing incidence of conditions such as obesity and diabetes that have arisen from modern lifestyles. Because we have traditionally relied on health services and health professionals to provide solutions to our health problems, we expect them to be available to support us when we have a health problem, even if the problem is a result of our own lifestyle. We collectively do not accept responsibility for our actions at a societal level, and, as a consequence, we are likely to face some serious challenges in the future when there will not be the resources available to meet societal demands in health, education, security and the environment (Fig. 8).

Fig. 7 Obesity in middle age—(www.davidwortley.com)

Fig. 8 Virtualware kinect serious game for rehabilitation—(www.virtualware.es)

Developments in serious games and immersive technologies can certainly support knowledge professionals to assist with training, diagnosis and treatment and also reduce the necessary skill levels required to deliver professional services, but with an increasing amount of intelligence being embedded into everyday ubiquitous technology, society is likely to be faced with serious shortages in key resources unless the empowerment that technology brings to the individual can also incorporate responsibility for self-management.

10 Internet of Things, Gamification and the Future of Serious Games and Immersive Technologies

This paper has charted the developments in the technologies that have shaped the world we live in today and illustrated how the relationships and structures that have formed the bedrock of our learning and development and the sustainability of society have been impacted by technology. Today, we face serious global challenges to the sustainability of services we have taken for granted in the developed world, and it is my belief that we need to develop strategies to address those challenges (Fig. 9).

My conclusion is that the ubiquitous sensor, visualisation and cloud technologies that are fast maturing will provide society with an opportunity to reconnect itself by linking citizen empowerment with responsibility for self-management. This can be achieved through the sensor technologies that form part of the Internet of Things and allow us to measure and feed back critical information and

Fig. 9 Jawbone UP lifestyle bracelet—(www.jawbone.com)

understanding that could shape our learning, development and capacity to take greater responsibility in the key areas of global challenges.

Instead of a world that is essentially structured and managed by silos of expertise with responsibility for specific sectors or disciplines, these technologies have the potential to build new structures with collaborative development and management in which individuals are motivated to take individual responsibility for managing their own lives as well as collective responsibility for contributing to sustainable models for society as a whole.

User-Generated Character Behaviors in Educational Games

Harri Ketamo

Abstract Games are the new form of storytelling and social interaction for younger generation. It might be surprising, but children are ready to do more work for their game characters than what they are ready to do for themselves. Because of this, we started to develop methods to enable user-generated character behaviours for educational games. In this paper, we show how user-generated behaviours can be recorded and shared in educational games. Furthermore, we demonstrate how user-generated behaviours can provide teachers and parents very detailed information about individual child's learning process.

Keywords Educational games · User-generated content · Character behaviors · Learning analytics

Games are the new form of storytelling and social interaction for younger generation. Furthermore, learning has always been about storytelling and social interaction. Keeping in mind that children are ready to do more work for their game characters than what they are ready to do for themselves, we started to develop methods to enable user-generated, taught, character behaviors for educational games. In this paper, we show how user-generated behaviors can be recorded and shared in educational games. According to ideas on this paper, game and media developers can design extensions that enable users to easily construct behaviors. Furthermore, we can demonstrate how user-generated behaviors, in SmartKid Maths elementary mathematics game, can provide teachers and parents very detailed information about individual child's learning process.

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O. Sourina et al. (eds.), *Subconscious Learning via Games and Social Media*,
Gaming Media and Social Effects, DOI 10.1007/978-981-287-408-5_5

1 Introduction

User-generated contents, such as game character's outfit, textures, and clothing as well as edited game scenarios, have been a solid part of games for a long time. It seems that users require features and activities that can be personalized and shared. However, there is no such interest for sharing behaviors, strategies, or game character personalities. After all, this is not completely because of lack of the technologies for modeling and sharing AI-related contents (Cowling 2006).

Unlike visual objects, behavior is a complex phenomenon. This complexity has set the limits to develop AIs that could enable behavior construction without programming or scripting. In fact, traditionally, AI programming requires not only programming skills, but also mathematical skills. Another discussion is that is game AI about intelligence or behavior. Baekkelund (2006) has argued that the game AI is far more difficult to determine than academic AI. Furthermore, when academic AI research focuses on perfect or optimal behavior, game AI should be entertaining: Game AI is allowed to cheat or be "stupid" in order to achieve the illusion about intelligent and entertaining behavior. In fact, it is easy to build perfect opponent; the challenge is to build entertaining opponent (Liden 2003; Scott 2002).

Behavior modeling has a long research background: Neural and semantic networks, as well as genetic algorithms, are utilized to model a user's characteristics, profiles, and patterns of behavior in order to support or challenge the performance of individuals. Behavior recording have been studied and used in the game industry for a good time. In all recent studies, the level of behavior is limited, more or less, to observed patterns (e.g., Brusilovsky 2001; Houllette 2003). Furthermore, agent negotiation and its scripted behavior (Kumar and Mastorakis 2010) as well as agent-based information retrieval (Popirlan 2010) in Web-based information systems have been studied for a long time.

Another research area related to character behaviors is agent communication studies. In economical game theory (Shoham and Layton-Brown 2009), an agent behavior is widely studied in terms of Nash equilibrium. In this, the agents are assumed to know the strategies of the other agents, and no agent has anything to gain by changing only its own strategy. A theory about existence of finite number of agents and their arbitrary relations based on other agent (Dukovska and Percikova 2011) describes a set of attributes or properties that are useful when evaluating the agent behavior: (1) every agent is an entity, (2) every agent exists even it does not have a physical characteristics, (3) every agent chose to be in a state of direct knowledge with other agent according to its free will, and (4) every agent is different from others in what it is.

Furthermore, there have been several good solutions in educational research that apply the idea of teaching the machines. For example, Hietala and Niemenrepo (1998) studied teachable agents as peer learners and Vogt (2005) introduces methods for applying teaching and guessing in language education. Maybe one of the best-known learning-by-teaching approaches in education is Betty's Brain (Biswas et al. 2005). The difference between previous research and this study is in the type of learning and the age of learners: When most of the solutions are based on deductive (top-down) type of learning, meant for students older than 16 years, this study focuses on inductive (from pieces to context) type of learning, meant for 6–10-year-old children.

In this study, user behavior, competence, and learning were seen as semantic (neural) network that produces self-organizing and adaptive behavior/interaction. The behavior is evaluated in terms of the theory about existence of finite number of agents. The AI technology developed emulates the human way to learn: According to cognitive psychology of learning, our thinking is based on conceptual representations of our experiences and relations between these concepts. Phenomena when the mental structure change is called learning.

The data mining and analytics are based on this semantic modeling. When all the skills and knowledge are recorded as semantic network, all the mining can be done in terms of network analysis. The novelty value of this study is in approach: to build game-based technologies for children that enable easy construction of intelligent and humanlike behaviors and so enables detailed analysis of learning achievements.

2 Recording Character Behaviors

The background of SmartKid Maths is in learning-by-doing, learning-by-teaching, and to some extent learning-by-programming. The approach is learner centric: The mechanics enables player to build his/her mental conceptual structures by adding new concepts into known ones. The framework is based on the author's previous work: Research articles have been published from the point of view of cognitive science (Ketamo and Kiili 2010; Ketamo and Suominen 2010; Kiili and Ketamo 2007) and from a technological point of view (Ketamo 2009, 2011). The AI behind framework emulates the human way to learn: According to cognitive psychology of learning, our thinking is based on conceptual representations of our experiences and complex relations between these concepts and experiences. Phenomena when the mental structure change is called learning.

SmartKind Maths connects learners to things they can experience on daily basis when teaching knowledge for their game characters. The game characters learn like humans do: inductively case by case by building relations between new and existing concepts. The AI consists of teachable agents: Each game character is a teachable agent that learns through interactions and evaluations during the gameplay. Computationally, the AI is based on semantic neural networks. The advantage of the method is in extensibility and scalability of learning: The AI can learn knowledge, behavior, and strategy even in undefined domains.

The background of SmartKid Maths is in learning-by-doing, learning-by-teaching, and to some extent learning-by-programming. The approach is learner centric: The game introduces mathematics in a way that learner can build his/her mental conceptual structures by adding new concepts into known ones. According to cognitive psychology of learning, people actively construct their own knowledge through interaction with the environment and through reorganization of their mental structures.

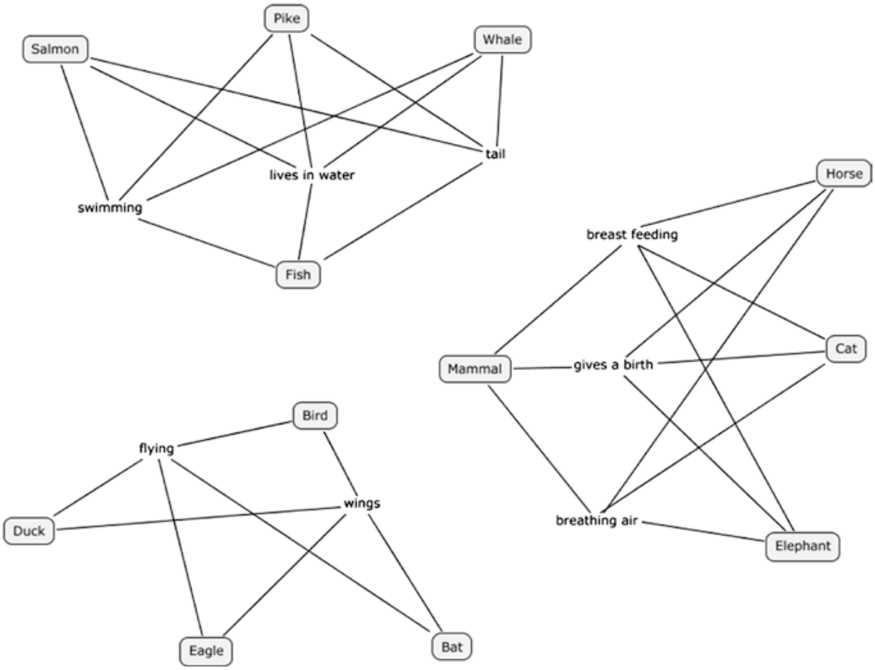

Fig. 1 Conceptual learning and assimilation process while learning the animals and their classification

When the player is responsible for character's mental development, he/she records also his/her mental conceptual structure during the gameplay. Eventually, we can say that while teaching his/her virtual character, learner reproduces a conceptual network about his/her mental conceptual structures.

In terms of constructive psychology of learning, people actively construct their own knowledge through interaction with the environment and through reorganization of their mental structures. The key elements in learning are accommodation and assimilation (e.g., Mayer 2004; Vosinadou 1994). Assimilation describes events when a learner strengthens his/her mental conceptual structure by means of new relations (Fig. 1). Accommodation describes an event when a learner figures out something radically new, which leads to a change in his/her mental conceptual structure (Fig. 2).

When child observes (Fig. 1) there are animals that live in the water, do have a tail, and they are swimming, he/she starts to construct conceptual understanding on fishes. Later, he/she connects animals like salmon, pike, and whale into fish category or schema. The same goes with concept of mammals, but maybe in a different way by first recognizing cat, dog, horse, etc. Later, child connects them as a group with properties like breathing an air, giving a birth, and breast-feeding.

When child observes that whale do have more mammal properties than fish properties (Fig. 2), he/she figures out that whale belongs to mammals, not fishes. This phenomena is called conceptual change. While assimilation is a phenomena on adding new concepts into our existing conceptual structure, accommodation

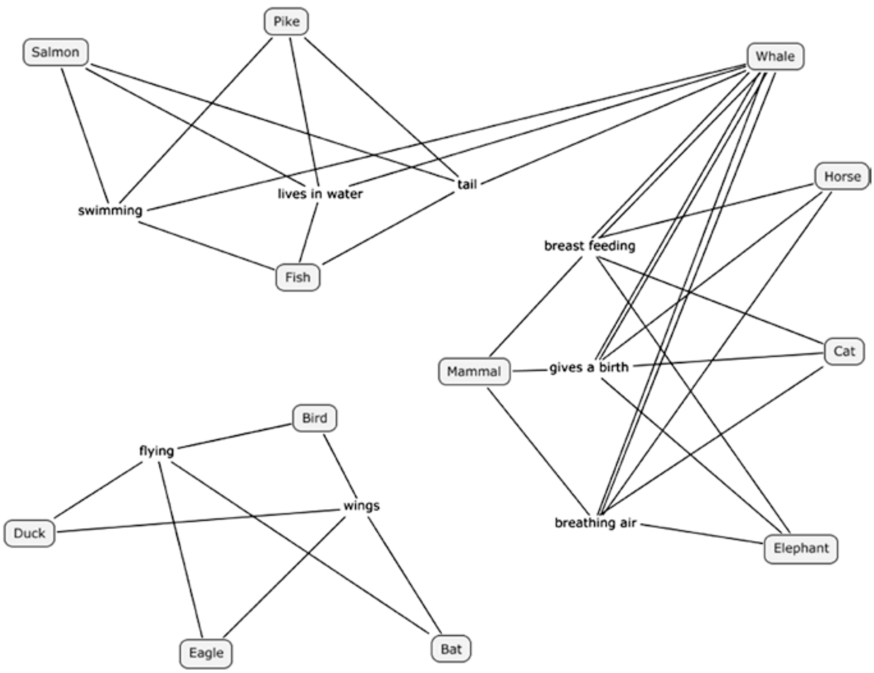

Fig. 2 Accommodation process and conceptual change when learning the animals and their classification

describes more radical changes in our thinking. From learning point of view, both phenomenas are important, but accommodation is far more difficult to observe, record or point out than assimilation. That is why most of the existing studies focus only on assimilation type of learning.

Furthermore, after several conceptual changes and confusing observations (Fig. 3), child will learn that knowledge is not black and white. All our understanding is based on complex set of concepts and their relations, and all concepts do have connections to several other concepts, properties, and categories. Child will also learn that meaning of the concept is depending on the context in which that concept is used. This kind of elastic conceptual structures is essential for further learning. If knowledge is learned as black-and-white rule-based system, that blocks not only a great share of future learning opportunities but also capabilities on thinking out of the box.

In SmartKid Maths, this theoretical framework is turned as game AI. The AI will learn like humans do: inductively case by case. Teaching is done in phase that consists of either a question creation and evaluation pair or evaluation process for computer generated question. Each teaching phase adds new relations into the conceptual structure in the same way as described in Figs. 1, 2, and 3. Accordingly, if the concept is not taught before, the new concept is also added into the conceptual structure during the teaching phase.

In teaching area of the game, the player helps his/her character with different tasks. In Fig. 4, the owl has asked a question about series and the character should

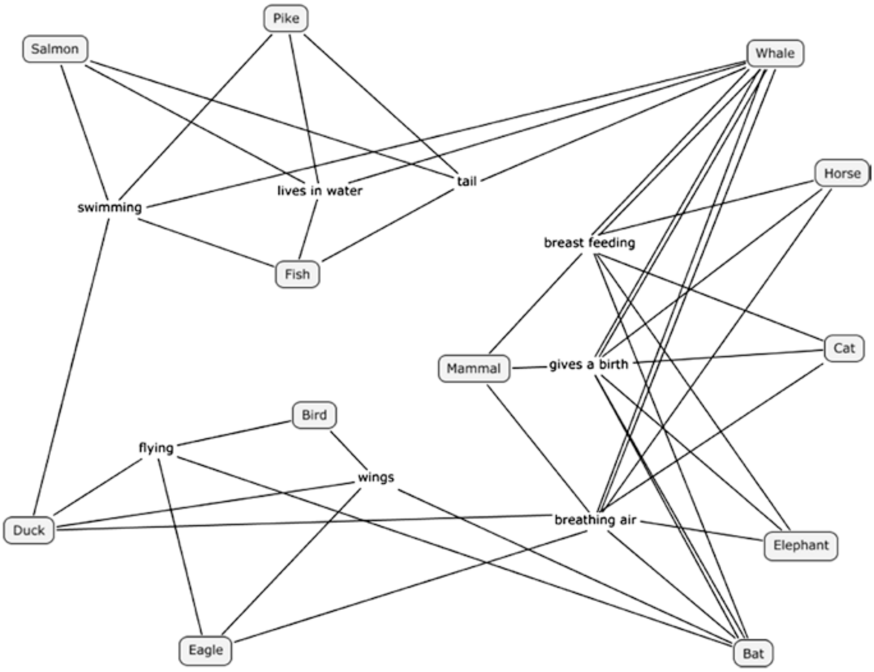

Fig. 3 Child has learned that knowledge is not black and white; there are always confusing connections in conceptual understanding

Fig. 4 Screenshot from SmartKid Maths teaching area

answer the question, but because it does not know, it asks player's help. The pet learns inductively, case by case. So, when player points the value 14, the AI learns that such series contain number 14 but not the rest of the numbers.

Accordingly, all the questions are evaluated by player and the AI will learn what the player thinks about relations between different concepts in the context of mathematics. Naturally, this will take a lot of evaluations and a lot of time, but that is the idea of the game: to take care of virtual character's cognitive development.

The character can also be taught wrongly, so when running the character behaviors, its behavior is incorrect. Teaching wrongly is an important part of the gameplay, and it is applied in the story: Some characters should be taught as stupid as possible in order to proceed. The game AI also does have "perfect brains," so analyzing the character performance is enabled.

3 Running Character Behaviors

The idea of the AI is that character behavior can be run no matter whether the player is online or not. Naturally, there must be enough teaching in order to produce reliable behavior. During only on couple of hours of gameplay, the semantic network in AI will evolve consisting of hundreds of concepts and thousands of relations between them (Fig. 5). The total playing time of SmartKid Maths is somewhere between 15 and 50 h, depending on players' existing skills and knowledge.

In the game side, this is visualized as a competition: A player can send his/her character to compete against any other non-player character or character taught by friends. The competitions are run in different labyrinths (Fig. 6), where the decision making is done according to taught behavior. In competition, the character is on its own, and all the performance is based on previous teaching.

Characters' task is to run through the labyrinths faster than their opponents. In every room, there is a statement and characters have to determine whether the statement is correct or not. This is done according to previous teaching.

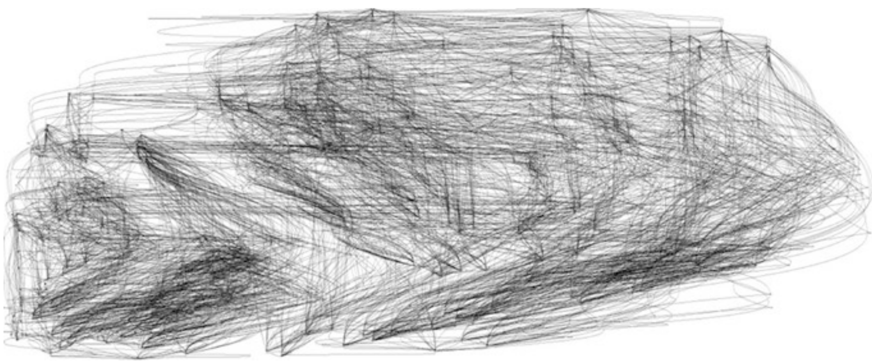

Fig. 5 Complex network of concepts and their relations taught during the gameplay

Fig. 6 Screenshot from competition in a labyrinth

The behavior in the labyrinth is based on complex set of player behavior during teaching the character: First of all, the selection of the correct answer is based on the state of the conceptual network in character's AI. The answer is not black and white; the reasoning will be based on all the taught relations in the network. In case player has not taught exactly some statement, character can determine the correct answer if there is critical mass of teaching done. So teaching more will give character better probability to determine the correct answer for the statement. This critical mass is also highlighted in game mechanics by increasing the character's running speed based on the size of the conceptual network.

The time/delay the character spends on thinking the answer is based on player's own thinking delays. The faster the player points out the correct answer, the faster the character will start to run.

When combining the delays in teaching and the correctness of the player's answers, we can predict (a) flow and (b) readiness to go to next level. In our previous studies (e.g., Ketamo and Multisilta 2003; Kiili and Ketamo 2007), we have found out that if a player is doing a lot of mistakes, but still working with fast interaction, he/she is in learning mode (Fig. 7). The same goes when player is using a lot of time before evaluating/answering the questions but doing little number of mistakes.

In all cases, when learner answers/evaluates the questions quickly and with small number of mistakes, he/she has learned enough on this small specific level and the player can be passed to next, more challenging, level.

This adaptive feature helps to maintain also flow experience by optimizing the balance between skills and competences. However, this formula works only in small well-defined domains with relatively simple and homogenous task. It is not meant to cover the whole domains, all the levels, or open-ended tasks.

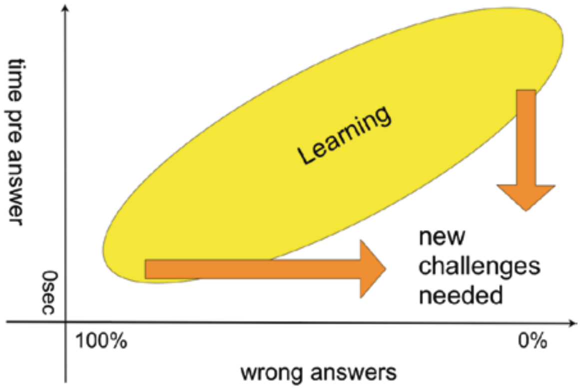

Fig. 7 Adaptive function for predicting whether the next level should be opened

In the game, the content in one level represents approximately one school week in Finnish school. Player can get bronze, sliver, or golden trophy when completing the level. Bronze trophy represents satisfactory skills, and golden trophy stars represent good skills. However, the results of the gameplay are always a bit fuzzy: Player can have just good luck and receive golden trophy with silver trophy performance. Furthermore, once in a while, a nearly perfectly taught game character can have non-optimal performance because of one difficult task. So the evaluation/assessment with SmartKid Maths in a single level is only indicative, but completing a whole grade requires skills that would be required to pass the same grade in a Finnish school.

The idea on running taught behaviors is that player can compete with or against any other player, no matter if she/he is online, because his/her character's behavior is online 24/7. The same ideas have been applied into sports games in authors' previous studies (Ketamo 2010; Ketamo et al. 2011). Furthermore, constructing different behaviors for different tasks requires strategic thinking.

4 Analytics Based on Character Behaviors

Games and other virtual environments can provide relevant and meaningful information for individual learner, his/her parents, teachers, and finally for educational system in a national level. In the following, we focus on (1) in-game analytics for player, parents, and teachers and (2) analytics tool for national curriculum development.

In-game analytics tool (Fig. 8) is meant for parents or teachers to quickly observe what learner has taught for his/her pet. The visualization shows correctly taught concepts in the upper part of the skills area and wrongly taught concepts in the lower part of the area. The quantity of the teaching is visualized in a way that concepts that are taught a lot appears in the right side of the area and little taught concepts on the left side. Quantity of teaching also means that what more relations a concept do have, that much right it is located. Concepts that have not been taught do not appear in the skills area.

Fig. 8 In-game learning analytic tool

When focusing on dependencies between the taught conceptual structure and pupils' achievements measured with traditional paper tests, we can find out that the taught conceptual structure is strongly related to paper test score received after gameplay ($0.4 < r < 0.7$) with all tested content on mathematics and natural sciences. This is an important result in terms of reliability of the game as assessment/evaluation instrument.

When going deeper in detail, wrong answers or misconceptions are not the only relevant factor explaining learning outcome. According to data received form gameplay, avoiding number (or concept) indicates directly poor performance in such concept. That is why the game forces learner also to pay attention to those concepts he/she is trying to avoid. Sooner or later, player will either learn these of such concepts will appear on the not-correct side of the analytics.

5 Conclusions

According to our studies, users can relatively quickly and easily teach behavior to a game character. In terms of conceptual learning, the developed AI emulates the way people learn: learning is about concepts and their relations. The behavior modeling makes it possible to model conceptual learning and thus uncover the frequencies, dependencies, and patterns behind conceptual change and learning transfer. These results show the strengths of sharing behaviors: Without capabilities of sharing the behavior, the kids would not spend that much time on school disciplines. On the other hand, if kids like the idea of sharing behaviors in an educational game, they would definitely love it in an entertaining game.

In the near future, user-generated behaviors can be developed and shared as all other user-generated content. Furthermore, game developers can design interfaces that enable users to teach versatile behaviors. User-generated behaviors can replace AI-controlled opponents or extend player's own team. Taught behavior model could be shared on the Web. Games and/or developers can upload user-generated behaviors either as AI updates and extensions, or in a development phase. From a game consumer point of view, the most interesting part is in developing behaviors, sharing them, and finally playing with them, or against them.

References

Baekkelund, C. (2006). Academic AI research and relations with the game industry. In S. Rabin (Ed.), *AI game programming wisdom 3* (pp. 77–88). Massachusettes: Charles river Media Inc.

Biswas, G., Leelawong, K., Schwartz, D., & Vye, N. (2005). Learning by teaching: A new agent paradigm for educational software. *Applied Artificial Intelligence, 19*(3–4), 363–392.

Brusilovsky, P. (2001). Adaptive hypermedia. *User Modeling and User-Adapted Interaction, 11*, 87–110.

Cowling, P. (2006). Writing AI as sport. In S. Rabin (Ed.), *AI game programming wisdom 3* (pp. 89–96). Massachusettes: Charles river Media Inc.

Dukovska, S. C., & Percinkova, B. (2011). A model that presents the states of consciousness of self and others. *International Journal of Mathematical Models and Methods in Applied Sciences, 5*(3), 602–609.

Hietala, P., & Niemenrepo, T. (1998). The competence of learning companion agents. *International Journal of Artificial Intelligence in Education, 9*, 178–192.

Houlette, R. (2003). Player modeling for adaptive games. In S. Rabin (Ed.), *AI game programming wisdom II*. Massachusetts: Charles River Media Inc.

Ketamo, H. (2011). Sharing behaviors in games and social media. *International Journal of Applied Mathematics and Informatics, 5*(1), 224–232.

Ketamo, H., Nurmi, C., & Kallama, K. (2011). User generated AI in sports education. In *Proceedings of the 5th European Conference on Games Based Learning*, *Athens, Greece* (pp. 306–314), October 20–21, 2011.

Ketamo, H., & Kiili, K. (2010). Conceptual change takes time: Game based learning cannot be only supplementary amusement. *Journal of Educational Multimedia and Hypermedia, 19*(4), 399–419.

Ketamo, H., & Suominen, M. (2010). Learning-by-teaching in an educational game: The educational outcome, user experience and social networks. *Journal of Interactive Learning Research, 21*(1), 75–94.

Ketamo, H. (2010). User generated AI's for sport games: Framework with semantic networks. In J. Wiemeyer & S. Göbel (Eds.), *Serious Games for Sports and Health: Proceedings of GameDays 2010*, *Darmstadt, Germany* (pp. 77–90), March 25–26, 2010.

Ketamo, H. (2009). Semantic networks-based teachable agents in an educational game. *Transactions on Computers, 8*(4), 641–650.

Ketamo, H., & Multisilta, J. (2003). Towards adaptive learning materials: Speed of interaction and relative number of mistakes as indicators of learning results. *Education and Information Technologies, 8*(1), 55–66.

Kiili, K., & Ketamo, H. (2007). Exploring the learning mechanism in educational games. *Journal of Computing and Information Technology, 15*(4), 319–324.

Kumar, S., & Mastorakis, N. E. (2010). Novel models for multi-agent negotiation based semantic web service composition. *WSEAS Transactions on Computers, 9*(4), 339–350.

Liden, L. (2003). Artificial stupidity: The art of intentional mistakes. In S. Rabin (Ed.), *AI game programming wisdom II*. Massachusetts: Charles River Media Inc.

Mayer, R. (2004). Should there be a three-strikes rule against pure discovery learning? *American Psychologist, 59*, 14–19.

Popirlan, C. I. (2010). Knowledge processing in contact centers using a multi-agent architecture. *WSEAS Transactions on Computers, 9*(11), 1318–1327.

Scott, B. (2002). The illusion of intelligence. In S. Rabin (Ed.), *AI game programming wisdom* (pp. 16–20). Massachusetts: Charles River Media Inc.

Shoham, Y., & Leyton-Brown, K. (2009). *Multiagent systems: Algorithmic, game-theoretic, and logical foundations*. New York: Cambridge University Press.

Vogt, P. (2005). The emergence of compositional structures in perceptually grounded language games. *Artificial Intelligence, 167*, 206–242.

Vosniadou, S. (1994). Capturing and modelling the process of conceptual change. *Learning and Instruction, 4*, 45–69.

Can We Play with ADHD? An Alternative Game-Based Treatment for Inattentive Symptoms in Attention-Deficit/Hyperactivity Disorder

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Abstract Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder presenting in early childhood with persistent, pervasive and impairing symptoms. It is also associated with other problematic mental health issues and negative outcomes, such as aggression, difficulties forming relationships and academic and occupational problems. Current standard treatments for ADHD include pharmacological treatments with stimulants and other medications, psychosocial interventions such as behavioural modifications, or a combination of both approaches (multi-modal approach consisting of parent education, medication and behaviour management for the child). There is interest in understanding effective non-pharmacological treatments for ADHD, given the temporary effects of medication and recent controversies on over-medicating children with ADHD. The use of neurofeedback treatment and cognitive training offers a promising new area for clinicians. We present a brain–computer interface (BCI)-based neurofeedback and cognitive training programme targeting the inattentive symptoms of ADHD in this chapter. The concept of an individualized model of attention is one of the features of the BCI training system. Incorporating this attention model into an innovative game targeted at ADHD children is another unique feature of this system. Recognizing the importance of validating serious games for the use of therapy, we have conducted several trials testing out the validity and playability of the BCI game, including a pilot phase and a larger randomized controlled trial. Currently, the future of this BCI-based treatment for ADHD is promising and we hope

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O. Sourina et al. (eds.), *Subconscious Learning via Games and Social Media*, Gaming Media and Social Effects, DOI 10.1007/978-981-287-408-5_6

that, through our research efforts, it may prove to be an effective and viable treatment option that also appeals to the game-playing nature of children.

Keywords Attention-deficit/hyperactivity disorder (ADHD) · BCI technology · Serious games · Alternative treatment

1 Introduction

Nathan rarely succeeds in finishing his math and language worksheets in class. He is in Primary 3 this year, and the workload at school is rapidly increasing. His teacher can see that he really wants to keep up, but he is finding it too difficult to sustain his attention on one thing at a time. He eventually ends up talking to his classmate next to him or running around in class. He has difficulty completing written assignments, misses out on questions, makes careless mistakes and forgets to do or hand in his homework. Though recognized by teachers to be a bright boy, he does poorly for the academic subjects and starts to lose interest in his studies. His classmates find him rough and noisy and are not keen to be his friends.

The description above is a rather common presentation of a child who has been diagnosed with ADHD. ADHD is a well-known neurodevelopmental disorder that is often associated with problematic outcomes throughout a person's life (Barkley 2002; Faraone et al. 2006; Young et al. 2010; Hodgkins et al. 2011). As it happens with most disorders, there is not only one, specific cause for the onset of ADHD, but it is better conceptualized as a combination of genetic, environmental and biological factors (Nikolas et al. 2010). The prevalence of ADHD worldwide is estimated to be between 5.9 and 7.1 % (Willcutt 2012; Polanczyk et al. 2014). In Singapore, ADHD is the third most serious public health concern for young people below 14 years old (Phua et al. 2009).

ADHD symptoms can be grouped under 3 major categories: inattention, hyperactivity and impulsivity. A child can be diagnosed to be either hyperactive/impulsive or inattentive or both inattentive and hyperactive/impulsive. We have included a full description of the clinical ADHD subtypes in Annex 1 (American Psychological Association 2013). Due to the symptoms described here, it is common for children with ADHD to struggle with everyday tasks. What is even more worrying for the child, however, is that these symptoms might cause disruptions in relationships with family, teachers and peers, academic difficulties throughout the school years, and in some cases, they may lead to school dropouts, delinquency and substance abuse in adolescence and adulthood (Barkley 2006; Biederman 2008; Sibley et al. 2010).

Traditionally, ADHD has been managed by a comprehensive treatment plan that includes psychological, behavioural and educational advice with the option of pharmacological intervention (Fabiano et al. 2009; Charach et al. 2011). For many clinicians and most parents, medication is not a preferred first-line treatment and it is reserved only for the severe cases and for those who have denied or not responded to non-pharmacological interventions. Medication helps to reduce hyperactive–impulsive and inattentive symptoms in individuals with ADHD. In Singapore, the only available stimulant medication is methylphenidate (Ritalin), a psychostimulant that has been available in the market for over 50 years, and remains the most common medication for the management of ADHD (Gadoth 2013). Atomoxetine, a relatively newer non-stimulant medication for treating ADHD, has been available for use over the past decade.

There are many trials for ADHD medications, indicating a range of side effects that are mild in intensity and short lasting (Sangal et al. 2006; Abikoff et al. 2007; Mosholder 2009). Some of the most common side effects are appetite suppression, growth retardation and cardiac side effects (stimulant-induced increases in mean blood pressure, heart rate and QT interval). Despite the existence of sound empirical background in literature, numerous clinicians have expressed their concern on whether the true dangers of such medication are known and fully understood (Graham et al. 2011), especially possible side effects that are rare and severe. Sudden death for example would be extremely difficult to investigate, since large numbers of subjects would be needed for recruitment, due to its rarity as event (Berger 2004). Another situation that seems to be on the rise in the last few years is the diversion of medication for misuse and abuse, especially during adolescence (Faraone et al. 2007; Rabiner et al. 2009; Setlik et al. 2009).

Studies have shown that even though medication can improve ADHD symptoms effectively, the improvement in academic grades is more modest and limited. Medication does not provide a solution for the problems related to children's academic performance and relationships with significant others, with the latter being a major distressing factor in a child's life (Chronis-Tuscano et al. 2013). Parents also seem not to favour medication, understandably, out of concern over the associated side effects and are often willing to try out non-pharmacological interventions first. Medication is also not seen as a permanent solution as the child does not learn to control or manage these troublesome symptoms.

There are a number of studies suggesting an advantage of non-pharmacological approaches over those of pharmacological treatment in terms of efficacy. Fabiano's meta-analysis published in 2009 strongly supports behavioural treatments for long-term effects on attention. Their results were partially duplicated by Hodgson et al. (2012) suggesting similar findings. Their evidence favours behavioural treatments, especially behaviour modification and neurofeedback. A more recent study reported that neurofeedback outperformed drug treatment (methylphenidate) for ADHD when measuring academic performance (Meisel et al. 2013). Evans et al. (2013) reviewed the growing literature on training interventions and provided guidance for conceptualizing the treatment research. According to them, there is a clear distinction between behaviour management and training interventions with the former being well-established treatments (e.g. behavioural parent training, behavioural classroom management and behavioural peer interventions). Training interventions, on the other hand, appear to be lacking strong, supporting evidence. A systematic review and meta-analysis by Sonuga-Barke and his colleagues (2013) on non-pharmacological interventions for ADHD strongly suggests the accumulation of additional evidence for the efficacy of behavioural interventions, neurofeedback and cognitive training.

An overview of reviews compared the efficacy and safety of non-pharmacological treatments to those related to drug therapies and control conditions of cognitive and behavioural symptoms of ADHD (Foisy and Williams 2011). The authors conclude that, for all interventions assessed, there was a lack of high-quality randomized controlled trials using standardized tools to measure clinically important outcomes over adequate periods of time. In the meantime, non-pharmacological interventions are becoming increasingly popular as people are more vigilant of the adverse effects of stimulant therapy. This increased demand for non-pharmacological therapies must be accompanied by rigorous scientific research in order to assess their efficacy.

Neurobiological studies, in an attempt to map the ADHD brain, show evidence suggesting that the brain of ADHD children is actually wired in a different way than non-ADHD children (Konrad et al. 2010; Loo et al. 2013). The latest approach in literature has overcome the idea of certain regions of the brain being dysfunctional. We are now talking about dysfunctional connectivity among regions; so, it appears to be more of an organizational matter rather than some specific areas of the brain not functioning properly (De la Fuerte et al. 2013). Some researchers have also differentiated the profiles of ADHD children in terms of cortical and subcortical abnormalities. Many children with ADHD seem to have an excess of theta wave activity and not enough beta activity (Arns et al. 2013). Theta waves are traditionally associated with internal focus and drowsiness, whereas beta waves are associated with external focus and alertness (Cortese 2012). It is also common to see an increase in theta activity when ADHD children are focusing on a task that is repetitive or uninteresting to them (Shiels et al. 2010).

It has been hypothesized that computer-based training may improve certain cognitive abilities such as working memory or attention in ADHD and become further generalized into other settings and everyday tasks (Klingberg 2002, 2005). A very common training programme is the Cogmed Working Memory Training. Several reviews of studies as well as recent randomized controlled trials examining cognitive remediation training for children with ADHD suggest evidence that is inconclusive (Rapport et al. 2013). Cogmed did not show evidence of reducing ADHD symptoms or generalized improvement in other functional domains. Also, there is not enough evidence to suggest that even when there is an improvement, this can sustain over time (Holmes et al. 2009; Klingberg et al. 2010). Jaeggi et al. (2011), on the other hand, suggest that cognitive training can be effective and long-lasting, but that there are limiting factors that must be considered to evaluate the effects of this training, one of which is individual differences in training performance.

There is a need for more research to investigate whether teaching good learning habits when young, such as attention control, might have positive long-term consequences even in the absence of the intervention. This is particularly important when it comes to attentional control, since this is one of the last cognitive abilities to develop in a typically developing brain (Ruff et al. 2003).

2 The Need for Validity Studies in Games for Intervention

There is an increasing use of games in treatment with the advent of serious games. Serious games are defined as games that are developed for purposes other than entertainment. There is a dearth of serious games being backed up by concrete research (Kato 2010). Since the onset of ADHD is during childhood, games appear to be a more effective way to engage these young children, in whom other psychological therapy such as cognitive behavioural therapy is usually more limited due to their limited cognitive abilities.

A review on the use of educational games to enhance classroom learning by Blakely et al. (2009) showed that gaming methods did not improve classroom learning any more than traditional teaching methods. Additionally, marketing efforts will be severely compromised if evidence-based research was not conducted on serious games, A New York Times article by Gabriel and Richtel (2011) reported on the heavy criticism faced by classroom educational software in which their marketing claims were not backed up by sound adequate evidence. All these point towards a future direction in which serious games need to go hand in hand with evidence-based research to market a well-validated game that would benefit patients and users the best way it can.

In order to ensure that validation research maintains the integrity of having a measurable impact on outcomes, a few guidelines have been suggested (Kato 2012):

1. Having a strong theoretical basis driving the development of the game
2. Conducting a randomized controlled trial: the gold standard for a clinical trial comparing treatment to control group
3. Pre- and postoutcome measures have to be objective
4. Negative side effects of the game have to be closely monitored

With these guidelines in mind, we would like to describe a brain–computer interface (BCI) treatment game that was developed for ADHD.

3 Brain–Computer Interface: A Research in Progress

The conceptualization of this game started with an academic psychiatrist who was the dean of a new medical school bringing together a practicing child psychiatrist and a research scientist who worked in the field of BCI and neural signals. Prior to this, research on BCI was largely done on patients with amyotrophic lateral sclerosis, a progressive neurodegenerative disease that affects brain abilities and muscle control. Such patients could not move very much and needed a way to manipulate objects with their brains. This was the main motivation for BCI. The team was interested in looking at the BCI technology and merging it with promising evidence that suggested neurofeedback training could improve attentional control in children. This development was also motivated by the increasing concerns throughout the world that children have been receiving far too much medication to treat attentional difficulties (O'Conner 2001; Blue 2012).

Using the traditional neurofeedback systems as a starting point, the team then developed with an algorithm that would translate each individual's innate attentional abilities to a quantifiable number. Observing the use of traditional neurofeedback, the team found that the use of theta/alpha/beta brainwaves as an attention index was not sensitive enough to detect accurate attention levels. Traditional neurofeedback treatment is also based on a global preset model, rather than an individually tailored model. Furthermore, the cost of these treatments tends to be high and have a long learning period. A recent meta-analysis on 14 neurofeedback studies on ADHD children found that this form of therapy is classified under ‘probably efficacious’ (Lofthouse 2012), a result that is promising but not sufficient to conclude on its efficacy. The team developed a more sensitive attention index by creating an algorithm that is a subject-dependent and personalized detection of attention. The algorithm is developed by using a machine learning approach to derive attention levels. The process involved collecting electroencephalogram (EEG), while the subject performs an attention task and a relaxation task. A classification model is then built to differentiate the two types of tasks using a filter bank. An attention score is thus generated by mapping the classification score to the scale of 1–100 (Hamadicharef et al. 2009).

Part of fulfilling the need for the model to be individualized and not based on a global model is involving a calibration task to measure each individual’s level of attention. The colour Stroop task was chosen to calibrate the algorithm to each individual subject, in which a written colour name is different from the colour ink it is presented in and the participant has to choose the written colour name. The colour Stroop task is a well-established neuropsychological measure (Stroop 1935), especially in measuring response inhibition in ADHD children (Lansbergen et al. 2007); it was chosen for the calibration task with the assumption underlying it that in order for the participant to get a correct answer, they have to be using a significant amount of concentration to inhibit the dominant reading response of the colour ink. Hence, the attention levels measured while the participants are doing the task would be taken as their maximum amount of attention, while the periods in between the task in which they are instructed to rest their eyes by rolling their eyes across the screen would be taken as their baseline relaxation state. Artefacts created by eye and facial movements were addressed through two methods: a wavelet approach to remove the artefact directly and a multiple-model approach based on bipolar EEG which is able to cancel out eye-blink movements (Krishnaveni et al. 2006).

Based on this system, the team analysed the critical EEG parameters during the correct attempts made by the participants and compared that to when the participants are in the relaxation state, to derive an individualized EEG pattern that would represent the participant’s most attentive state. This model is a unique feed-forward system as it makes use of an individual’s direct attention to control aspects of a game.

4 Pilot and Phase 1 Trials

A small pilot trial was conducted to investigate the efficacy and feasibility of using this BCI-based training programme to improve inattentive symptoms of ADHD. Certain considerations governed the design of the game: for it to be repeatable and simple, not too distracting but engaging enough to sustain interest and finally, to examine the minimum sufficient time needed for the intervention to take effect. Using a traditional EEG set-up to administer the intervention, 10 ADHD participants were enrolled to play a simple two-dimensional car racing game for 20 sessions (2 sessions per week for 10 weeks) using the BCI technology, with another 10 participants recruited as controls.

Results from this small trial were promising. The inattentive scores on the ADHD Rating Scale IV (Dupaul 1991) were the primary outcome measure used in this trial. This ADHD Rating Scale is based on the DSM-IV criteria for ADHD and consisted of 9 inattentive and 9 hyperactive symptoms. Three measures can be obtained from this scale: an inattentive score, a hyperactive score and a total score, with higher scores indicating worse symptoms. The main outcome measures were changes in the inattentive scores. A nonparametric Mann–Whitney U-test was used to compare the intervention to the control group. Mean changes for the intervention group were −3.0 (SD = 4.8) and control group 0.8 (SD = 1.3), although the two groups did not differ significantly (Mann–Whitney $U = 16.0$, $p = 0.053$) (Lim et al. 2010).

After the pilot trial was completed, a more intensive BCI game training programme was investigated in a second trial to test whether training over a shorter period of 8 weeks would be as acceptable to parents. The number of training sessions and duration of training were increased from 20 sessions over 10 weeks to 24 sessions over 8 weeks. Additionally, preliminary analysis of the first pilot results appeared to suggest that improvements were sustained 3 months after intervention. The team decided to add booster training sessions, which follow the same BCI training procedures, of one session per month for 3 months. This would follow after the 8-week intensive training, thereby increasing the entire training programme to 20 weeks. A total of 20 participants were recruited for this second pilot trial.

Additionally, technical changes were also made to the device and system. The traditional EEG cap introduced a lot of artefacts in the EEG waves collected due to eye-blink movements. This was replaced with a dry EEG electrode device headband (see Fig. 1, NeuroSky, Inc, USA), with only 2 electrodes measuring brainwaves associated with attention at the prefrontal cortex. A grounding reference electrode is clipped to the ear, and the headband is connected to the computer through wireless Bluetooth technology. Game developers were also engaged to improve the design of the game and make it more interactive and appealing to children. A three-dimensional graphic game, Cogo™ Land, was thus developed specifically for the purpose of the training game. Enhanced visual feedback was also included, and difficulty levels were introduced as an additional element to the game.

Results from this study were very positive (Lim et al. 2012). Parents were asked to complete the same ADHD Rating Scale IV at baseline (0 weeks), end of the treatment sessions (8 weeks) and after the follow-up session (24 weeks). There were significant reductions in the inattentive scores at week 8, with paired t-tests used to assess the changes in scores. At week 8, the mean (SD) change from week 0 was −4.6 (5.9) and median (range) change was −3.0 (−17.0, 4.0) which was statistically significant ($p = 0.003$). However, there were no statistically significant changes of parent-reported inattention scores after booster session. This suggests that although the

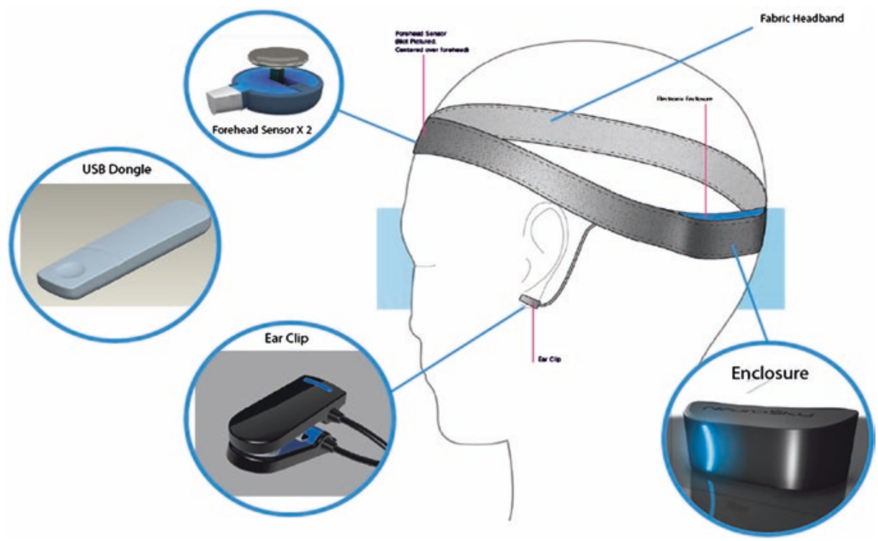

Fig. 1 Illustration of the BCI headband

booster sessions did not significantly improve symptoms further, they served to sustain the effects found from the 8 weeks of intensive training. We also found improved ratings in the hyperactivity score which could be due to the highly structured training environment and behavioural skills learnt through playing the game.

Following the encouraging results of the initial studies, a randomized controlled trial was planned to recruit 160 participants with ADHD. Study procedures and headband design were kept similar, and the study is currently ongoing.

5 Current Randomized Controlled Trial

In our current ongoing study, participants are randomized into either an intervention group or a wait-list control group. The study procedures are kept similar to the previous trials with 8 weeks of BCI training followed by 3 monthly booster sessions.

Participants who are randomized into the intervention group are started on the BCI training immediately, whereas participants in the control group were defined as wait-list controls and did not receive any intervention during the first 8 weeks. Instead, they are started on the BCI training from week 9 onwards. A wait-list group comparison, rather than a sham or placebo control, was introduced to address the ethical caveat of a subset of participants not receiving any form of interventions throughout the duration of their involvement. The time-points of week 1 and week 8 provide a direct comparison of participants who have gone through 8 weeks of intervention versus participants who did not receive any intervention for 8 weeks. Further details on this study can be found on the ClinicalTrials.gov Website (ClinicalTrials.gov 2014).

6 Game Design

The platform on which the BCI treatment is administered to the ADHD participants is known as Cogo^{TM} Land. In Cogo^{TM} Land, an animated bird avatar chosen by the participant will run around an island. The speed at which the bird runs will be based on the participant's level of concentration. This level of attention is measured through the headband device (see Fig. 1), which detects and sends the EEG signals to the computer. An algorithm-derived attention index is then generated and fed back to the participants in the form of a Brain Score from 0 to 100, with 100 being the highest level of attention. The participants are able to monitor their Brain Score changes on the screen as they play the game.

Participants are instructed to focus their attention in order to increase their Brain Score. Once their level of attention drops below their individually calibrated threshold, the avatar stops running until the participant focuses hard enough to get their attention levels above the threshold. The motivation in the game is thus to make the avatar run as fast as it can.

A point system is also integrated in the game, where participants are encouraged to score higher points through various means. There are 3 levels of difficulty in the game. In the first beginner level, the participant is required to run around an island using his concentration. They are rewarded points based on the number of laps they run around the island. In the second intermediate level, the participants have to press a button to jump and collect fruits while using their concentration to make the bird run. They collect the fruits in random order and are awarded points based on the correct attempts at collecting fruits. The final advanced level is the same procedure as the intermediate level, only at this stage; they are required to collect the fruits in a specific order. Again, points are given for correct attempts. Figure 2 shows screenshots of the game at the 3 difficulty levels.

A transference task, which consists of 20 academic questions adjusted for each child's grade level, is administered to the participant at the end of every alternate session. This transference task was added in due to huge concerns of academic impairment in ADHD children (Daley and Birchwood 2010), and there is interest in observing whether the participants would be able to generalize the behavioural contingencies learn through the BCI treatment to an academic setting.

7 Validating the BCI Treatment in ADHD

In developing innovative new treatments for ADHD, there is a need to identify important steps in doing this systematically.

1. Having a strong theoretical basis driving the development of the game
   In order to develop a cogent theory for exploring alternative treatments, the team conducted a series of brainstorming sessions with both basic scientists and clinicians to better understand the existing treatment modalities as well as gaps in the

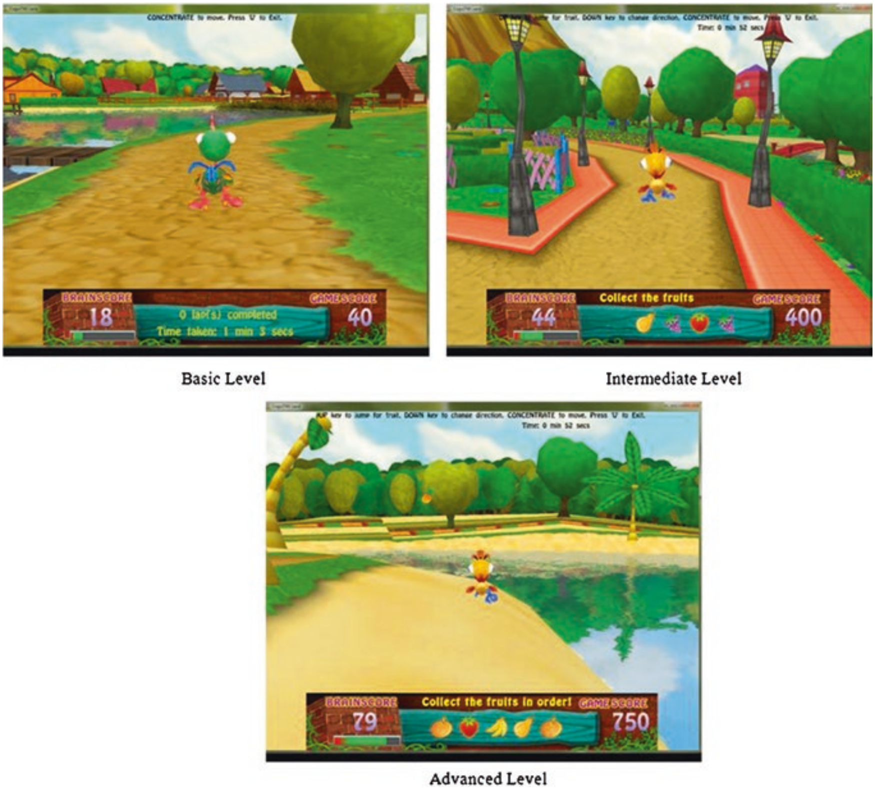

Fig. 2 Screenshot depictions of BCI Cogo^{TM} Land gameplay

current systems of care. Extensive reviews on what neurofeedback and other cognitive training systems are currently available were also done. This then allowed us to develop the BCI system so as to improve what was already available.

2. Conducting a randomized controlled trial: the gold standard for a clinical trial comparing treatment to control group
   Smaller scale studies were conducted to observe the feasibility and effectiveness of the BCI game system on children. With promising results of parent-reported reduction in inattentive symptoms, a randomized controlled trial is currently being conducted to maintain the integrity in the results that were previously observed.
3. Pre- and postoutcome measures have to be objective
   The primary outcome measure of the studies is the ADHD-RS, which is a well-validated tool for measuring symptoms of ADHD. In phase 1 of our trial, we included teacher's ADHD-RS ratings as a 'blinded' measure to improve objectivity of the ratings. However, due to poor response rates, the teacher responses were inconclusive. In our randomized controlled trial, we improved on our design by making our research clinicians blinded instead of relying on teacher's ratings.

4. Adverse effects of the game have to be closely monitored
   Throughout all the trials conducted, participants were closely monitored in terms of any discomfort or issues faced. Aside from feelings of fatigue and minor headaches experienced by one or two participants, no adverse events were reported. Furthermore, the headaches experienced by the participants did not stop them from continuing with the treatment.

8 Back to the Future

Video games have taken the limelight away from Hollywood (Ryan et al. 2006; Yi 2004), as they now appear to be the world's most common entertainment medium. Their popularity varies according to certain socio-demographic factors, for example age, sex, religion, income and education (Williams 2008), but there is no doubt that a respectable number of people are hooked on online gaming. There are a lot of controversies surrounding the game industry and the consequences it might have on the person. Some of the negative effects might be immunity to the horror of violence (Sherry 2001), increase of body weight (Vandewater 2004) and poorer work/school performance (Gentile 2011). The DSM 5 has also included Internet game disorder as a possible diagnostic category for future versions. The positive outcomes of gaming are definitely the entertainment and fun factor and the fact that they provide a sense of control over a situation (Jones 2002). Some also suggest that video games are an optimal opportunity for learning purposes (Gee 2003). BCI technology allows game development to bring in an entire new dimension of control that players have. This is in line with the progress that games consoles such as the Nintendo Wii and the Xbox Kinect (and now Xbox One) have done.

In developing the BCI game to treat ADHD children we had to consider how the game, the person and the device that all work together in a continuous feedback loop which is self-adapting.

A unique element of the BCI game is the calibration feature; the participant performs the colour Stroop task so as to generate a personalized EEG profile of the user's optimal attentive state. Intervals of resting stage are also included so there are also data of the individual when he is relaxing, providing a pattern of their most inattentive state. Every person is different; therefore, the BCI mechanism achieves a regulation of attention that serves different individual needs. The tailored nature of the BCI is associated with an additional benefit. By being personalized, the treatment becomes both motivating and meaningful for the person. Gameplay is intrinsically motivating but receiving feedback that addresses only to your personal needs can mean extra motivation and surrounds the whole experience with explicit meaning. Subsequently, when an experience is both motivating and meaningful, it can also serve as an optimal opportunity to learn. And when we use the word 'learn', we do not restrict the term only to knowledge acquisition or skill practice, but we are also talking about exploration, critical thinking and problem-solving (Green 2012).

Video games offer players sensational action, competitive rewards and captivating stories, exactly what the ADHD brain demands. It is the sort of stimuli that can rarely be brought together in the real world. Most games that exist in the market have all the above but they also include the violent component. Anderson's meta-analysis in 2010 gathers strong evidence to support that violent video games have a causal relationship with aggressive behaviour and decreased empathy (Anderson 2010). He and his colleagues suggest that the effects of violent games on children do not seem to discriminate among different cultures or gender. Everyone seems to be equally susceptible to the effects of violence. For these reasons, it seems to be quite a relief when games targeted to children are designed without the violent factor, such as Cogo™ Land. This is an attempt to maintain the positive features of the game playing and leave behind the more controversial aspects of it.

Another benefit of the treatment game is generalizability: the ability to gradually build something stronger and then transfer this trained skill to other situations. The literature demonstrates that cognitive training works and that transfer effects may even persist over time, but we need to consider possible limitations that transference is bound to have individual differences for example. Games are supposed to be directly linked to enjoyment; however, this depends heavily on the user and the situation. While some consider challenges or competition as most enjoyable, others find enjoyment in repetitive and low challenging activities (Harrison 1992).

Some children seem unable to engage and benefit from the training. A plausible explanation might be lack of interest during training, or difficulty coping with the frustrations of the task as it becomes more challenging. This would suggest that though useful in many, the BCI game is not suitable for all. Some concerns have also been raised about whether this intervention can cause 'addiction' to computer games. This is highly unlikely considering that the game can only be played in a specific time and place leaving no space for excessive use. In addition, playing the game demands a sustained level of concentration which is hard to maintain for prolonged periods of time. Hence, the game has been designed to be addiction-intolerant. In addition to that, the time restrictions that this treatment offers can also help children with ADHD manage their time in a more constructive way. Time management is particularly important for individuals with ADHD, an element particularly fundamental when we are talking about quality of life.

This present game treatment, however, does not provide a panacea for all the difficulties that accompany ADHD. Except inattentiveness and/or hyperactivity, children with ADHD often have conduct problems, usually characterized by defiance and aggressive behaviour. Such problems make it difficult for the child to find his role at school, in peer relationships and within the family. Emotional problems may also be present, leading the child feeling isolated and experiencing low self-esteem. These behaviours may be more troublesome than the ADHD symptoms alone, and the game by no means claims to provide treatment for these issues.

Some of the challenges that accompany this research study relate to the content of the game. Although it has 3 difficulty levels, the actual game procedures do not vary much, resulting in a rather repetitive mode of playing. Therefore, some children seem to grow out of it relatively quickly. To encourage motivation, we have come up with a reward system, where the child collects stickers at the end of every session and he gets an extra sticker only if he scores better than his previous session. The stickers are eventually exchanged with a present. This reward system was incorporated into the game so as to increase and sustain motivation. For the same reason, we entered different levels of gaming, with an increasing factor of difficulty, so as to keep engagement levels high. Therapists who attend to the sessions are always in the assessment room together with the child, ensuring the proper conduct of the treatment and at times providing verbal encouragement to the participant.

We propose that future research should focus on the complexity of the software of the BCI treatment, creating increasingly more sophisticated simulations for the children to take part. We also suggest that the ultimate goal of the BCI treatment must be transference; therefore, the training techniques must be designed with this idea in mind. A more in-depth understanding of the profile of the individuals who will benefit from these types of intervention is also an area that has not been adequately investigated yet.

We now have a better understanding on how the brain works and the communication of different neural pathways that are involved when cognitive processes take place. The overall literature appears clear in that most positive effects on cognitive training come with suitable attentional allocation and resource management. However, application of these findings to education is still in an experimental stage.

Children spend most of their time either at home or at school, and they develop relationships with others within these environments. Ideally, treatments should be implemented at both home and school (Eiraldi 2012), and take into account the variables that we have discussed, which might hinder or enhance training.

Annex 1

DSM-5

A. Either (1) or (2):

1. **Inattention**:

Six (or more) of the following symptoms of inattention have persisted for at least 6 months to a degree that is inconsistent with developmental level and that negatively impacts directly on social and academic/occupational activities:

Note: The symptoms are not solely a manifestation of oppositional behaviour, defiance, hostility or failure to understand tasks or instructions. For older adolescents and adults (age 17 and older), at least 5 symptoms are required.

(a) Often fails to give close attention to details or makes careless mistakes in schoolwork, at work or during other activities (e.g. overlooks or misses details, work is inaccurate).
(b) Often has difficulty sustaining attention in tasks or play activities (e.g. has difficulty remaining focused during lectures, conversations or lengthy reading).

(c) Often does not seem to listen when spoken to directly (e.g. mind seems elsewhere, even in the absence of any obvious distraction).
(d) Often does not follow through on instructions and fails to finish schoolwork, chores or duties in the workplace (e.g. starts tasks but quickly loses focus and is easily sidetracked).
(e) Often has difficulty organizing tasks and activities (e.g. difficulty managing sequential tasks; difficulty keeping materials and belongings in order; messy, disorganized work; has poor time management; fails to meet deadlines).
(f) Often avoids, dislikes or is reluctant to engage in tasks that require sustained mental effort (e.g. schoolwork or homework; for older adolescents and adults, preparing reports, completing forms, reviewing lengthy papers).
(g) Often loses things necessary for tasks or activities (e.g. school materials, pencils, books, tools, wallets, keys, paperwork, eyeglasses, mobile telephones).
(h) Is often easily distracted by extraneous stimuli (for older adolescents and adults, may include unrelated thoughts).
(i) Is often forgetful in daily activities (e.g. doing chores, running errands; for older adolescents and adults, returning calls, paying bills, keeping appointments).

2. **Hyperactivity and impulsivity**:

Six (or more) of the following symptoms of hyperactivity–impulsivity have persisted for at least 6 months to a degree that is inconsistent with developmental level and that negatively impacts directly on social and academic/occupational activities:

Note: The symptoms are not solely a manifestation of oppositional behaviour, defiance, hostility or failure to understand tasks or instructions. For older adolescents and adults (age 17 and older), at least 5 symptoms are required.

(a) Often fidgets with or taps hands or feet or squirms in seat.
(b) Often leaves seat in situations when remaining seated is expected (e.g. leaves his or her place in the classroom, in the office or other workplace or in other situations that require remaining in place).
(c) Often runs about or climbs in situations where it is inappropriate (Note: in adolescents or adults, may be limited to feeling restless).
(d) Unable to play or engage in leisure activities quietly.
(e) Is often 'on the go', acting as if 'driven by a motor' (e.g. is unable to be or uncomfortable being still for extended time, as in restaurants, meetings; may be experienced by others as being restless or difficult to keep up with).
(f) Often talks excessively.
(g) Often blurts out an answer before a question has been completed (e.g. completes other people's sentences; cannot wait for turn in cwwwonversation).
(h) Often has difficulty waiting his or her turn (e.g. while waiting in line).
(i) Often interrupts or intrudes on others (e.g. butts into conversations, games or activities; may start using other people's things without asking or receiving permission; for adolescents or adults, may intrude into or take over what others are doing).

A. Several inattentive or hyperactive–impulsive symptoms were present prior to age 12.
B. Several inattentive or hyperactive–impulsive symptoms are present in two or more settings (e.g. at home, school or work; with friends or relatives; in other activities).
C. There is clear evidence that the symptoms interfere with, or reduce the quality of, social, academic or occupational functioning.
D. The symptoms do not occur exclusively during the course of schizophrenia or another psychotic disorder and are not better explained by another mental disorder (e.g. mood disorder, anxiety disorder, dissociative disorder, personality disorder, substance intoxication or withdrawal).

Specify whether:

314.01 (F90.2) **Combined Presentation**: If both Criteria A1 and A2 are met for the past 6 months
314.00 (F90.0) **Predominantly Inattentive Presentation**: If Criterion A1 is met, but Criterion A2 is not met for the past 6 months
314.01 (F90.1) **Predominantly Hyperactive–Impulsive Presentation**: If Criterion A2 is met, but Criterion A1 is not met for the past 6 months.

References

Abikoff, H. B., Vitiello, B., Riddle, M. A., et al. (2007). Methylphenidate effects on functional outcomes in preschoolers with attention deficit/hyperactivity disorder treatment study (PATS). *Journal of Child and Adolescent Psychopharmacology, 17*, 581–592.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). Arlington, VA: American Psychiatric Publishing.

Anderson, C. A., Shibuya, A., Ihori, N., et al. (2010). Violent video game effects on aggression, empathy and prosocial behavior in Eastern and Western countries: A meta-analytic review. *Psychological Bulletin, 136*(2), 151–173. doi:10.1037/a0018251.

Arns, M., Conners, C. K., & Kraemer, H. C. (2013). A decade of EEG theta/beta ratio research in ADHD: A meta-analysis. *Journal of Attention Disorders, 17*(5), 374–383.

Barkley, R. A. (2002). Major life activity and health outcomes associated with attention-deficit/hyperactivity disorder. *Journal of Clinical Psychiatry, 63*, 10–15.

Barkley, R. A. (2006). *Attention deficit hyperactivity disorder: A handbook for diagnosis and treatment*. New York: Guilford Press.

Berger, S., Utech, L., & Fran Hazinski, M. (2004). Sudden death in children and adolescents. *Pediatric Clinics of North America, 51*(6), 1653–1677.

Biederman, J., Petty, C. R., Wilens, T. E., et al. (2008). Familial risk analyses of attention deficit hyperactivity disorder and substance use disorders. *American Journal of Psychiatry, 165*(1), 107–115.

Blakely, G., Skirton, H., Cooper, S., et al. (2009). Educational gaming in the health sciences: Systematic review. *Journal of Advanced Nursing, 65*, 259–269. doi:10.1111/j.1365-2648.2008.04843.x.

Blue, L.(2012). *Are ADHD drugs in short supply*? TIME. http://healthland.time.com/2012/01/03/are-adhd-drugs-in-short-supply/. Accessed February 27, 2014.

Charach, A., Dashti, B., Carson, P. et al. (2011). *Attention deficit hyperactivity disorder: Effectiveness of treatment in at-risk preschoolers; long-term effectiveness in all ages; and* *variability in prevalence, diagnosis, and treatment*. Comparative effectiveness review No. 44. Agency for Healthcare Research and Quality. http://www.effectivehealthcare.ahrq.gov/ehc/products/191/818/CER44-ADHD_20111021.pdf. Accessed March 12, 2014.

Chronis-Tuscano, A., Chacko, A., Barkley, R. (2013). Key issues relevant to the efficacy of behavioral treatment for ADHD. *The American Journal of Psychiatry*, *170*, 799. doi:10.1176/appi.ajp.2013.13030293.

ClinicalTrials.gov. (2014). *National Library of Medicine* (NLM), Maryland. http://www.clinicaltrials.gov/ct2/show/NCT01344044?term=brain+computer+interface&rank=4. Accessed March 2, 2014.

Cortese, S. (2012). The neurobiology and genetics of attention-deficit/hyperactivity disorder (ADHD): What every clinician should know. *European Journal of Paediatric Neurology, 16*(5), 422–433.

Daley, D., Birchwood, J. (2010). ADHD and academic performance: Why does ADHD impact on academic performance and what can be done to support ADHD children in the Classroom? *Child Care Health and Development*, *36*(4), 455–464. doi:10.1111/j.1365-2214.2009.01046.x.

De La Fuente, A., Xia, S., Branch, C., et al. (2013). A review of attention-deficit/hyperactivity disorder from the perspective of brain networks. *Frontiers in Human Neuroscience, 7*, 192. doi:10.3389/fnhum.2013.00192.

Dupaul, G. J. (1991). Parent and teacher ratings of ADHD symptoms: Psychometric properties in a community-based sample. *Journal of Clinical Psychology, 20*, 242–253.

Eiraldi, R. B., Mautone, J. A., & Power, T. J. (2012). Strategies for implementing evidence-based psychosocial interventions for children with attention-deficit/hyperactivity disorder. *Child Adolescent Psychiatric Clinics, 21*(1), 145–159. doi:10.1016/j.chc.2011.08.012.

Evans, S. W., Owens, J. S., Bunford, N. (2013). Evidence-based psychosocial treatments for children and adolescents with attention-deficit/hyperactivity disorder. *Journal of Clinical Child & Adolescent Psychology*, *43*(4), 527–551.

Fabiano, G. A., Pelham, W. E, Jr, Coles, E. K., et al. (2009). A meta-analysis of behavioural treatments for attention-deficit/hyperactivity disorder. *Clinical Psychology Review, 29*(2), 129–140. doi:10.1016/j.cpr.2008.11.001.

Faraone, S. V., Biederman, J., & Mick, E. (2006). The age-dependent decline of attention deficit hyperactivity disorder: A meta-analysis of follow-up studies. *Psychological Medicine, 36*(2), 159–165.

Faraone, S. V., & Wilens, T. E. (2007). Effect of stimulant medications for attention-deficit/hyperactivity disorder on later substance use and the potential for stimulant misuse, abuse and diversion. *Journal of Clinical Psychiatry, 68*(suppl 11), 15–22.

Foisy, M., & Williams, K. (2011). The Cochrane library and non-pharmacological treatments for attention deficit hyperactivity disorder in children and adolescents: An overview of reviews. *Evidence-Based Child Health: A Cochrane Review Journal, 6*(2), 283–297. doi:10.1002/ebch.731.

Gabriel, T., Richtel, M. (2011). *Grading the digital school: Inflating the software report card*. The New York Times. http://www.nytimes.com/2011/10/09/technology/a-classroom-software-boom-but-mixed-results-despite-the-hype.html?pagewanted=all&_r=0. Accessed February 27, 2014.

Gadoth, N. (2013). Methylphenidate (Ritalin): What makes it so widely prescribed during the last 60 years. *Current Drug Theraphy, 8*(3), 171–180.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave Macmillian.

Gentile, D. A. (2011). The multiple dimensions of video game effects. *Child Development Perspectives, 5*(2), 75–81. doi:10.1111/j.1750-8606.2011.00159.x.

Graham, J., Banaschewski, T., Buitelaar, J., et al. (2011). European guidelines on managing adverse effects of medication for ADHD. *European Child and Adolescent Psychiatry, 20*(1), 17–37. doi:10.1007/s00787-010-0140-6.

Green, C. S., & Bavelier, D. (2012). Learning, attentional control and action video games. *Current Biology, 22*(6), R197–R206. doi:10.1016/j.cub.2012.02.012.

Hamadicharef, B., Zhang, H., Guan, C., et al. (2009). Learning EEG-based spectral-spatial patterns for attention level measurement. In *IEEE International Symposium on Circuits and Systems* (ISCAS), May 24–27.

Harrison, A. W., & Rainer, R. K, Jr. (1992). The influence of individual differences on skill in end-user computing. *J Management Information Systems, 9*(1), 93–111.

Hodgkins, P., Arnold, L. E., Shaw, M., et al. (2011). A systematic review of global publication trends regarding long-term outcomes of ADHD. *Frontiers in Psychiatry, 2*, 84. doi:10.3389/fpsyt.

Hodgson, K., Hutchinson, A. D., & Denson, L. (2012). Non pharmacological treatments for ADHD: A meta-analytic review. *J Attention Disorders,*. doi:10.1177/s1087054712444732.

Holmes, J., Garthercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science, 12*(4), F2–F7. doi:10.1111/j.1467-7687.2009.00848.x.

Jaeggi, M. S., Buschkuehl, M., Jonides, J., et al. (2011). Short- and long-term benefits of cognitive training. *Proceedings of National Academic Science USA,*. doi:10.1073/s1103228108.

Jones, G. (2002). *Killing monsters: Why children need fantasy, super heroes, and make-believe violence*. New York: Basic Books.

Kato, P. M. (2010). Video games in health care: Closing the gap. *Review of General Psychology, 14*(2), 113–121.

Kato, P. M. (2012). Evaluating efficacy and validating games for health. *Game Health Journal, 1*(1), 74–76. doi:10.1089/g4h.2012.1017.

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology, 24*, 781–791.

Klingberg, T., Fernell, E., Olesen, P. J., et al. (2005). Computerized training of working memory in children with ADHD—A randomized, controlled trial. *Journal of American Academy of Child Adolescent Psychiatry, 44*, 177–186.

Klingberg, T. (2010). Training and plasticity of working memory. *Trends in Cognitive Science, 14*, 317–324. doi:10.1016/j.tics.2010.05.002.

Konrad, K., & Eickhoff, S. B. (2010). Is the ADHD brain wired differently? A review on structural and functional connectivity in attention deficit hyperactivity disorder. *Human Brain Mapping, 31*(6), 904–916. doi:10.1002/hbm.21058.

Krishnaveni, V., Jayaraman, S., Anita, L., et al. (2006). Removal of ocular artifacts from EEG using adaptive thresholding of wavelet coefficients. *Journal of Neural Engineering, 3*(4), 338.

Lansbergen, M. M., Kenemans, J. L., Engeland, H. V., et al. (2007). Stroop interference and attention-deficit/hyperactivity disorder: A review and meta-analysis. *Neuropsychology, 21*(2), 251–262. doi:10.1037/0894-4105.21.2.251.

Lim, C. G., Lee, T. S., Guan, C., et al. (2012). A brain-computer interface based attention training programme for treating attention deficit hyperactivity disorder. *PLoS ONE, 7*(10), e46692. doi:10.1371/journal.pone.0046692.

Lim, C. G., Lee, T. S., Guan, C., et al. (2010). Effectiveness of a brain-computer interface based programme for the treatment of ADHD: A pilot study. *Psychopharmacology Bulletin, 43*, 73–82.

Lofthouse, N., Arnold, L. E., Hersch, S., et al. (2012). A review of neurofeedback treatment for pediatric ADHD. *Journal of Attention Disorders, 16*(5), 351–372. doi:10.1177/1087054711427530.

Loo, S. K., Cho, A., Hale, T. S., et al. (2013). Characterization of the theta to beta ratio in ADHD identifying potential sources of heterogeneity. *Journal of Attention Disorders, 17*(5), 384–392. doi:10.1177/1087054712468050.

Meisel, V., Servera, M., Garcia-Banda, G., et al. (2013). Neurofeedback and standard pharmacological intervention in ADHD: A randomized controlled trial with six-month follow-up. *Biological Psychology, 94*, 12–21. doi:10.1016/j.biopsycho.2013.04.015.

Mosholder, A. D., Gelperin, K., Hammad, T. A., et al. (2009). Hallucinations and other psychotic symptoms associated with the use of attention-deficit/hyperactivity disorder drugs in children. *Pediatrics, 123*, 611–616. doi:10.1542/peds.2008-0185.

Nikolas, M. A., & Burt, S. A. (2010). Genetic and environmental influences on ADHD symptom dimensions of inattention and hyperactivity: A meta-analysis. *Journal of Abnormal Psychology, 119*(1), 1–17. doi:10.1037/a0018010.

O'Conner, E. M. (2001). *Medicating ADHD: Too much? Too soon?* American Psychological Association. Available via Monitor on Psychology. http://www.apa.org/monitor/dec01/medicating.aspx. Accessed February 27, 2014.

Phua, H. P., Chua, A. V., Ma, S., et al. (2009). Singapore's burden of disease and injury. *Singapore Medical Journal, 50*(5), 468–478.

Polanczyk, G. V., Willcutt, E. G., Salum, G. A., et al. (2014). ADHD prevalence estimates across three decades: An updated systematic review and meta-regression analysis. *International Journal of Epidermiology,*. doi:10.1093/ije/dyt261.

Rabiner, D. L., Anastopoulos, A. D., Costello, E. J., et al. (2009). The misuse and diversion of prescribed ADHD medications by college students. *Journal of Attention Disorders, 13*(2), 144–153. doi:10.1177/1087054708320414.

Rapport, M. D., Orban, S. A., Kofler, M. J., et al. (2013). Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. *Clinical Psychology Review, 33*(8), 1237–1252. doi:10.1016/j.cpr.2013.08.005.

Ruff, H. A., & Capozzoli, M. C. (2003). Development of attention and distractibility in the first 4 years of life. *Developmental Psychology, 39*(5), 877–890.

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

Sangal, R. B., Owens, J., Allen, A. J., et al. (2006). Effects of atomoxetine and methylphenidate on sleep in children with ADHD. *Sleep, 29*, 1573–1585.

Setlik, J., Bond, G. R., & Ho, M. (2009). Adolescent prescription ADHD medication abuse is rising along with prescriptions for these medications. *Pediatrics, 124*(3), 875–880. doi:10.1542/peds.2008-0931.

Sherry, J. L. (2001). The effects of violent video games on aggression: A meta-analysis. *Human Communication Research, 27*(3), 409–431. doi:10.1111/j.1468-2958.2001.tb00787.x.

Shiels, K., & Hawk, L. W, Jr. (2010). Self regulation in ADHD: The role of error processing. *Clinical Psychology Review, 30*(8), 951–961. doi:10.1016/j.cpr.2010.06.010.

Sibley, M. H., Pelham, W. E., Molina, B. S., et al. (2010). The delinquency outcomes of boys with ADHD with and without comorbidity. *Journal of Abnormal Child Psychology, 39*(1), 21–32. doi:10.1007/s10802-010-9443-9.

Sonuga-Barke, E. J., Brandeis, D., & Cortese, S. (2013). Nonpharmacological interventions for ADHD: Systematic Review and meta-analyses of randomized controlled trials of dietary and psychological treatments. *American Journal of Psychiatry, 170*(3), 275–289. doi:10.1176/appi.ajp.2012.12070991.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643–662.

Vandewater, E. A., Shim, M. S., & Caplovitx, A. G. (2004). Linking obesity and activity level with children's television and video game use. *Journal of Adolescence, 27*(1), 71–85.

Willcutt, E. G. (2012). The Prevalence of DSM-IV attention-deficit/hyperactivity disorder: A meta-analytic review. *Neurotherapeutics, 9*(3), 490–499. doi:10.1007/s13311-012-0135-8.

Williams, D., Yee, N., & Caplan, S. E. (2008). Who plays, how much, and why? Debunking the stereotypical gamer profile. *J Computer Mediated Communications, 13*(4), 993–1018. doi:10.1111/j.1083-6101.2008.00428.x.

Yi, M. (2004). *They got game: Stacks of new release for hungry video enthusiasts mean its bloom time for an industry now even bigger than Hollywood*. San Francisco Chronicle. http://www.sfgate.com/news/article/THEY-GOT-GAME-Stacks-of-new-releases-for-hungry-2663371.php. Accessed February 26, 2014.

Young, S., & Amarasinghe, J. M. (2010). Practitioner Review: Non-pharmacological treatments for ADHD: A lifespan approach. *Journal of Child Psychology and Pschiatry, 51*(2), 116–133. doi:10.1111/j.1469-7610.2009.02191.x.

Associating Sport Skills Through Virtual Games: An Introductory Approach

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Abstract According to NORMA™ Engaging Multimedia Design (NEMD)Model, engagement is determined by levels. The model suggests that anything could be learned, mastered and acquired when a person reach a high level of engagement while interacting with a multimedia interface. An experimental study was conducted to prove whether this claim is true. A sport virtual game was chosen as a vehicle for this study. The chosen sport game must be one that is unfamiliar to the selected audience; in this case, children to ensure that the skills gained were because of the fact of engagement and not because of the influence of previous knowledge about the game. The purpose was to see whether playing an engaging sports game virtually, even though the game is an unfamiliar one, could influence children in acquiring sports skills when playing it in the physical world. The chosen sport game was Rugby, a not widely known sport to children aged 9–10 years old in Malaysia's Primary School Education. The game is only introduced in Secondary Schools. In NEMD model, a game is engaging if the game can sustain users' attention for a period of 2 h and more. There are two forms of data gathered. One, the recorded facial expressions and gestures of subjects to prove that the game is very engaging and another, the screenshots of skills of recorded performance in two contrasting spaces, virtual and real. In the virtual space, the children played the virtual game for a period of 2 h. In real-life space, the children played the actual game in the playing field. Data gathered have proven that an engaging virtual game could, not only, engaged children in playing the game but also assist them to acquire sports skills taught in real-life situations at a fast speed. The children were able to associate sports skills in Rugby such as scrum, swing, punt, throw-in, drop kick, tackling and catching when playing in the field. The game gave them a holistic view of the game thus enable them to grab meanings of these movements when introduced to the game much faster than the traditional

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O. Sourina et al. (eds.), *Subconscious Learning via Games and Social Media*,
Gaming Media and Social Effects, DOI 10.1007/978-981-287-408-5_7

"one skill at a time introduction", much used when teaching sports games such as football and netball. These findings have given a good basis to suggest sports training divisions to use sport skills in virtual games as an introductory approach to teach young teenagers to play sports, for this case, Rugby.

Keywords Sports skills · Sports games · Games · Engaging · Virtual games · Computer games · Teaching materials · Teaching methods · Metacognition

1 Introduction

We cannot deny the fact that our teenagers and children are now growing in an era of new technologies convergences in computer game applications, virtual reality, augmented reality, the Internet, mobile technology, GPS technology, sensor technology and other software technologies. These convergences are happening in our homes, in mobile phones, recreation centres such as theme parks, entertainment centres and exhibition halls such as museum, science centres and others. These convergences will cause our kids to be engaged and addicted to computer games hence missing out on their responsibility as a student. Our children are so engaged that they forget about homework, assignments and learning. They become very aggressive and sometimes get very irritable at us if we disturb them when they are playing. Yet a lot of advantages have been found from playing computer games such as improving skills on logical thinking, strategic planning, problem-solving, including cognitive and metacognitive strategies that will increase skills in divergent thinking. It is about time we think of ways to manipulate something that is negative about engagement in playing computer games, where prolonged engagement could lead to addiction, into something positive such as learning.

2 NEMD Model

"NEMD Model—Norma™ Engagement Multimedia Design Model" (Said 2007a) was an extended research developed in Universiti Putra Malaysia (UPM) through observations and experimental studies of young teens in engaging situations as they interact with computers (Said 2004). The model has been created into a patented system to measure engagement not discussed in this paper. The system uses a NORMA experimental setting to measure engagement. NORMA is an acronym for Natural Observation and Reflection of Multimedia Application (Said 2011a).

The model engagement features and factors (Said 2011a) have contributed a lot to the reasons why teenagers become addicted to computer games. Applying engagement factors in the NEMD's Model to a Student-Centred Learning (SCL), teaching methodology (Said 2007b) has shown positive impact to the teaching and learning process experienced by UPM's students taking the course. They were not only engaged and highly motivated to the task given to them but also able to produce optimum learning outcomes. By including the engaging features in the NEMD Model in a text design of an "interactive illustration" of a preschool book series *"Siri 3 Sahabat dan SiRama-Rama"*, correctly used by the nurseries of *TABIKA Perpaduan* in Malaysia, *Jabatan Perpaduan dan Integrasi Nasional*, the children were able to remember what we wanted them to remember when they reached a level of being engaged (Said 2011b). The children could remember the names of the characters, stories, scripts and the rhymes in these books instantly. When these features were included in a reference book *Multimedia Integrasi Siri 1* (Said 2010), users of the book make the book not as a book to be put on the shelf after reading it but to look at it sometime in the future to recollect memories of converting theories to practise.

Thus from these findings, it was convinced that the engagement features should be placed in the education curriculum of schools and higher educational institutions to encourage students addicted to learning so that a positive learning outcomes could be established and lifelong learning habits could be instilled in our future generation. The technology should be applied in several products that are being used in schools such as books, teaching materials and teaching aids to help children becoming more engaged with their lessons in classroom. Parents could also learn how to choose some materials to entice the minds of our children towards positive learning experience at home. Even though the advancement in technology is rapid and we seemed to be "aiming at a moving target", humans are still humans. Our responses to sensation and feelings remain consistent and universal in technological and non-technological driven conditions.

3 Associating Sports Skills Through Virtual Games

This paper will present how a chosen virtual sports games were used as a vehicle to prove a claim by NEMD Model. According to NORMA™ Engaging Multimedia Design (NEMD) Model (Said 2011), anything could be learned, mastered and acquired when a person reach a high level of engagement while interacting with a multimedia interface. The chosen sport game must be the one that is unfamiliar to the selected audience; in this case, children to ensure that the skills gained were not because of the influence of previous knowledge about the game but because of the fact of engagement. The purpose was to see whether playing an engaging sports game virtually, even though the game is an unfamiliar one, could influence children in acquiring sports skills when playing it in the physical world. The research was done to see whether children can associate these skills when playing the game physically in real time.

4 4.0 Why Rugby?

The chosen sport game for this research was Rugby. Rugby was chosen because it is not a widely known sport to children aged 9–10 even to 12 years old in Malaysia's Primary School Education. The game is only introduced when children entered Secondary Schools. This paper will discuss how the sports skills of Rugby got from playing virtual game has successfully helped children acquire skills in playing Rugby in the playing fields at a very fast speed. The chosen virtual sports game was EA Sport Rugby '08, Publication: EA Sport Ltd. (2008) (2008).

5 Description of the EA Sport Rugby '08

EA SPORTS™ celebrates the 2007 Rugby World Cup™ with the only official and exclusive licensed video game that captures the emotion and passion of the world's fiercest national rivalries. **Rugby 08** (EA Sport Ltd. 2008) (Fig. 1) is the 2007 release in the Rugby series by EA Sports. The game allows players to play as many Rugby nations, both major and minor, and includes many tournaments, such as the Rugby World Cup, Tri Nations, Six Nations, Guinness Premiership and Super 14. *Rugby 08* was released prior to the 2007 World Cup in France. New mode include the Rugby World Cup and the World Cup Challenge mode. Other new game play features include simplified line-outs and defensive formations.

Rugby '08 game is divided into several stages, namely identification, selection of players and teams, tutorials, support and help in controlling the game. Some of the features are presented in Figs. 2 and 3.

The game also gives some explanation, history and tutorials on various basic Rugby skills for players to understand and learn some terminologies and how to manipulate it.

Introduction Page | Choose team and players | Hints and Tips | Players

Fig. 1 The EA Sport Rugby '08

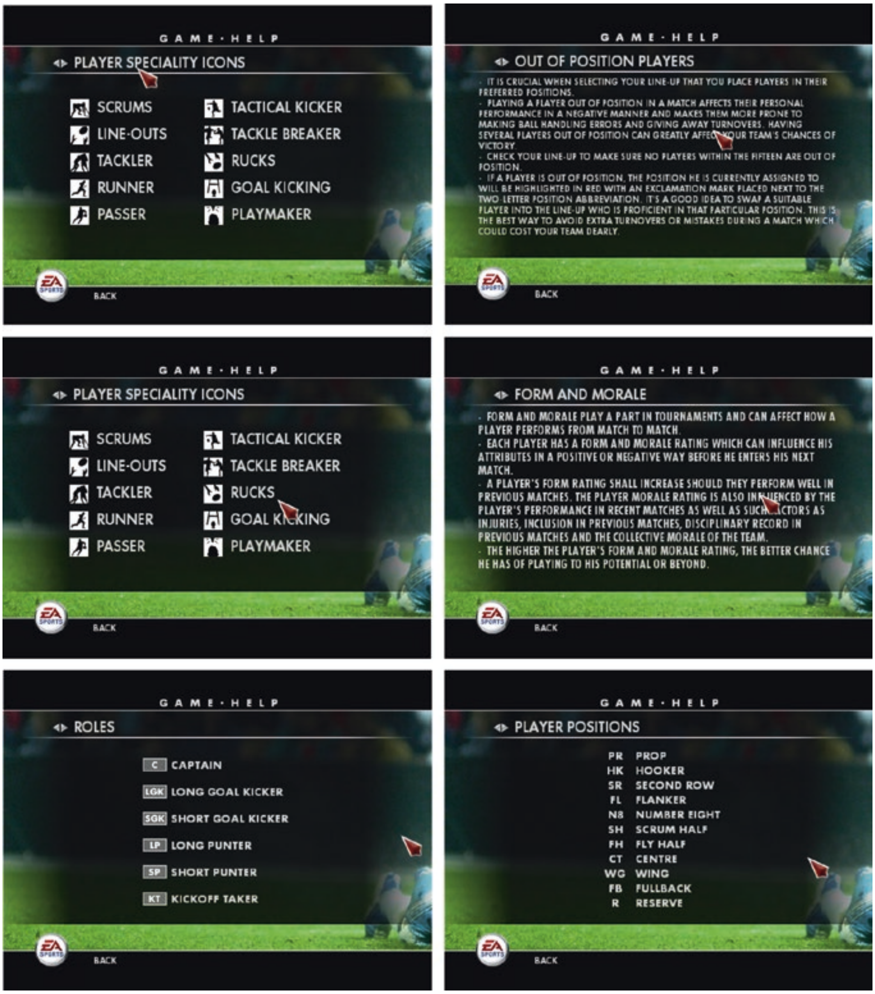

Fig. 2 Games help

Fig. 3 Control help

6 Some Basic Skills and Tutorials

(a) Scrum: Rugby's unique formation, the forerunner of the American football line of scrimmage, is the method used to restart the game after the referee has whistled a minor law violation. A bound group of players from each team form a "tunnel" with the opposition. The non-offending team puts the ball into the tunnel by rolling it into the middle, and each team pushes forward until one player is able to hook the ball with the feet and push it to the back row players of his/her team. The scrum half then retrieves the ball and puts it into play
(b) Kick to goal

   i. Penalty kick: Awarded after a serious infringement of the law. Offenders are required to retreat 10 yards, while the opposing team is given the opportunity to restart play unopposed. Teams will often kick the ball up field and out of bounds to gain field advantage. When they do this, the play is restarted as a line-out where the ball goes out of bounds. If in range, they may attempt a kick at the goalposts, worth three points. Finally, they may simply tap the ball with their foot and run with it.
   ii. Free kick: This is awarded after a less serious infringement of the law. The free kick is similar to the penalty kick except a player cannot attempt a kick at goal to try to score three points. A player must restart with a tap kick or attempt to kick the ball out of bounds. If the kick is made from in front of the 22-metres (25 yards) line and goes directly out of bounds, the line-out occurs back where the kick was first kicked. If the ball bounces out of bounds, or if the kick was taken from behind the 22-metre (25 yards) line, the resulting line-out is where the ball crossed the touch line.
   iii. Drop kick: A kick made when the player drops the ball and it bounces off the ground prior to being kicked. Worth three points if it travels through the goalposts. Drop kicks are also used to restart play after a score.
   iv. Running: When running the ball, players may continue to run until they are tackled, step out of bounds or run beyond the goal line (see scoring a try). Players run the ball to advance towards the opponent's goal line.

Figure 4 show some of the skills taught in the tutorial section of this game application on *Goal Kicking*. Other skills include *kicking*, *line-out /throw-in*, *passing, ruck, scrum, sprinting and scoring* and *tackling* (2008).

7 Research Methodology

This research (Izwardi and Yusoff 2011) was conducted in 2 days over a weekend. A group of children were given to play the computer game full day on Saturday from 10 am to 5 pm and half day on Sunday from 10 a.m. to 2 p.m. and from 2 p.m. to 7 p.m. that Sunday evening they went to play the actual game in the field.

Fig. 4 Goal kicking

8 Subjects

There are 10 children involved in this research. All of them are boys aged 12 years old from a Standard 6 class students studying at a local Primary School in Malaysia. They are volunteered participants involving in this experiment as an after school activity.

9 INSTRUMENTS

A number of instruments were used to carry out this research:

1. THE EA SPORT RUGBY ‘08, virtual sports multimedia game application, was used as a vehicle for carrying out this research.
2. Video recording equipment
3. Two computers.

10 Objectives of Research

The objectives of this study are as follows:

1. To prove that the game is an engaging game.
2. To prove that engagement could assist children in associating sports skills in virtual games to real-life physical situations.

11 Research Arrangement

To meet the two objectives set for this research, the research was crafted into two phases. In Phase one, the children, in this experiment, were given to play the virtual game in a classroom for a period of 2 hours. In Phase two, the children played the actual rugby game in the playing field. Phase one was to prove that this game is an engaging game, and the other phase was to prove that without prior knowledge about the game of rugby, children experiencing engaging situations could transmit knowledge and skills of what they have received through virtual presentation to real-life situations at a fast speed.

11.1 Phase One

The children were placed in pairs to play the game at any one time using a given joysticks. Each child was given the chance to play the game three times. The Phase one was divided into two sessions: one slightly structured, while another freeplay. In the slightly structured session, the children were given to play the *Rugby `08* for 2 hours using joystick. A video camera was placed in front and at the back of the children to record every movement, facial expressions and exclamations made by them. The purpose was to see whether the game is really an engaging one. In this structured session, there were a few interventions when the children were playing the game. In these interventions, children were asked to focus on some basic rugby skills such as "passing the ball", "catching the ball" and "drop kick". In the second session of Phase one the children were just asked to play the game without any intervention for 2 hours. Every movement, facial expressions and exclamations were also recorded in this session.

11.2 Phase Two

In Phase two all 10 children were asked to go down to the field and played the actual game on the field. They were divided into two teams and each group consisting of 5 children. The children were given a RUGBY ball and instructed to perform the movements according to the skills they have to focus during intervention in the structured play of Phase one. The children played the actual rugby for 2 hours in the field.

12 Findings and Analysis of Study

From the data collected of this study, the research gathered from (Izwardi and Yusoff 2011) has proven to meet its two objectives, that is, that the game is an engaging game and the other that engagement could assist children in associating sports skills in virtual games to real-life physical situations. Some of the data can be seen in the captured shots in the figures given.

12.1 Phase One

There are two procedures being done to analyse the data in this phase, which is, identifying the skills to be focused on during intervention and another to see whether the game is really engaging.

(a) Skills Identification Examples

The skills identified for intervention are as follows:

I. Scrum
II. Swing
III. Drop kick
IV. Catching
V. Throw-in
VI. Tackle
VII. Punt
VIII. Kick at a Goal

IX. Run

(b) Engaging Environment Examples

Research to develop NEMD MODEL has proven that a game is engaging if the game can sustain users' attention for a period of 2 h and more. Evidence of engagement can be got from data of facial expressions of users as they played the game. Facial expressions and exclamations of engagement include that of a fully engrossed image, smiling, laughing, clapping of hands and other body languages besides exclamations such as Ooh!, Wow!, Cool!, Best! and Yes!. (Izwardi and Yusoff 2011; Izwardi et al. 2009a, b. Analysis of the data obtained from Phase one has proven that the game THE EA SPORT RUGBY '08, virtual sports multimedia game application,

Fig. 5 An engaging facial expression and engaging moments which catch the attention of others

is an engaging game. Engaging moments were captured through the video recordings when the children were playing the game (Izwardi and Yusoff 2011; Izwardi et al. 2009a, b. By analysing their facial expressions and exclamations, it was proven that the game is an engaging game. Video evidence can be seen in Fig. 5.

13 Findings and Analysis of Phase Two

After playing the computer game, the children were then asked to play the actual game on the field. Findings from this phase are that the children were able to associate what they see in the virtual game to the situation in the real world thus proving that engagement has given children some form of associating skills to the sports game being played. Some examples of the skills acquired are given in Figs. 6, 7 and 8.

Fig. 6 Scrum in virtual game versus scrum in actual field play

Fig. 7 Drop kick in virtual game versus drop kick in actual field play

Fig. 8 Tackle in virtual game versus tackle in actual field play

I. SCRUM
II. DROP KICK
III. TACKLE.

14 Discussions and Conclusion

The purpose of this research was to prove the statement according to NORMA™ Engaging Multimedia Design (NEMD) Model (Said 2004, 2007a, 2011a, c) that anything could be learned, mastered and acquired when a person reach a high level of engagement while interacting with a multimedia interface. This research has proven that an engaging virtual game could, not only engage children in playing the game but also assist them to associate sports skills they encountered with those taught in real-life situations, thus proving that anything could be learned, mastered and acquired when a person reach a high level of engagement while interacting with a multimedia interface. A reference to metacognitive strategies explained in detail in Said et al. (2008, 2009) could give us some form of idea what really happens as the child played in an engaging multimedia environment, perhaps will be discussed in future papers .

The lessons learned, mastered and acquired from engaging situations could be positive or negative. However, an effort of making engagement an educational advantage (Said 2006) could put some games to good use in our educational system especially as in that of sports games. The research discussed above is a good example of this. The children in this research were able to associate sports skills in Rugby such as scrum, swing, punt, throw-in, drop kick, tackling and catching when playing the game on the field. They were able to get a holistic picture of how the game is played and thus able to grabs meanings of these movements when introduced to the game much faster than the traditional "one skill at a time introduction", much used when teaching sports games such as football and netball .

Therefore as a conclusion, findings from this research have given us a good basis to suggest sports training divisions to use sport skills in virtual games as an introductory approach to teach young teenagers to play sports games, for this case, Rugby. The approach could not only fasten the acquisition rate of required games sport skills but also instil a sustainable engaging experience for better sport performances of our future sports enthusiasts.

Acknowledgement We would to thank Serious Games & Social Connect 2013 for inviting the main author as one of the Keynote Speaker for this event. A great appreciation to Universiti Putra Malaysia (UPM) for giving us the opportunity and support to continually pursue research on games under the Games, Serious Games and Gamification Research Group from funding of the RUGS (Research University Grant Scheme), UPM. Special thanks are also conveyed to the Prototype Research Grant Scheme (PRGS) offered by the Ministry of Education under the Higher Education Division of the Government of Malaysia in supporting the development of a system to measure engagement and addictiveness. The system was initiated from this research and other researches on engagement and addictiveness in multimedia application. We hope our findings will make engagement as an educational advantage.

References

EA Sport Ltd. (2008). Multimedia application. EA Sport Rugby '08 Publication.

Izwardi, M., & Yusoff, M. (2011). *Implikasi Bahasa Visual dalam Permainan Ragbi*. Unpublished Master's Thesis, Faculty of Modern Languages and Communication, Universiti Putra Malaysia, Malaysia.

Izwardi, M., Yusoff, M., & Said, N. S. (2009a). Bahasa Visual dalam Permainan Berkomputer Sebagai Penyebaran Ilmu. PROSIDING PERSIDANGAN ANTARABANGSA BAHASA MELAYU BAHASA DUNIA m.s 629–638. September 28–30, 2009. Pusat Konvensyen Antarabangsa Persada Johor, Johor Bahru.

Izwardi, M., Yusoff, M., Said, N. S., Zaitul, A., Zainon, H., Adi, Y., et al. (2009b). Interpretasi Bahasa Visual dalam Permainan Ragbi Berkomputer. Bahasa Melayu Dalam Pembinaan Sahsiah Dan Jati Diri Negara Bangsa Seminar Linguistik Dan Pembudayaan Bahasa Melayu Ke-V. m.s 230–234. November 17–18, 2009. FBMK, UPM.

Said, N. S. (2004). An engaging multimedia design model. In *Proceedings of Interaction Design and Children 2004 Building a Community*, Maryland, USA (Vol. 15(2), pp. 169–172). http://www.idc2004.org, June 1–3, 2004. New York: ACM Digital Library, The Association of Computer Machineries (ACM) Press. ISBN 1-58113-791-5.

Said, N. S. (2006). Engaging children to multimedia: What factors to consider when designing for children. In The 3rd International Conference on Educational Technology, September 7–9, 2009. Singapore Expo at www.icet.com.sg.

Said, N. S. (2007a). *An engagement model—A modeling theory that explains engagement whist interacting with a multimedia design application*. DIGITAL LEARNING ONLINE DL Asia 07/ABS /162. www.digitallearning.in.

Said, N. S. (2007b). engaging learning through student-centred learning (SCL) approach (pp. 144–156). Monograph Pengajaran Dan Pembelajaran Ipta. Pusat Pembangunan Akademik (CADe), UPM: Serdang. ISBN 978-983-3168-12-5.

Said, N. S. (2010). *Multimedia Integrasi—Reka Bentuk Berpusat Pengguna*. Serdang: UPM Press. ISBN 978 - 967 - 344 - 156 - 3.

Said, N. S. (2011a). X-factor in a multimedia engagement behaviour—The NEMD model (Norma™ Engagement Multimedia Design Model)”. In Prakash, E., & Murugesan, S. (Eds.), *Proceeding of the 4th Annual Conference on Computer Games, Multimedia and Allied Technology* (CGAT 2011), Hotel Equatorial Penang, Malaysia. April 25–26, 2011. ISBN 978-981-08-8644-8.

Said, N. S. (2011b). engaging children to story tell in a text design context by using engagement features in NEMD (Norma™ Engagement Multimedia Design Model). In *Proceedings of International Educational Technology Conference*, IETC 2011, Istanbul University, Istanbul, Turkey. May 25–27, 2011.

Said, N. S. (2011c). Children’s preferences in design of multimedia application. *World Applied Sciences Journal*, *14*(Special Issue of Innovation and Pedagogy for Diverse Learners), 64–71. ISSN 1818-4952.

Said, N. S., Rahman, S., Yassin, S. F. M. (2008). A case study on metacognitive strategies in an engaging multimedia experience. In *Proceedings of the 7th WSEAS International Conference on Education and Educational Technology* (Edu’8), Venice, Italy, November 21-23, 2008, pp. 224–230. WSEAS Press. www.wseas.org ISSN: 1790-5109. ISBN: 978-960-474-029-1.

Said, N. S., Saemah, R.,& Yassin, S. F. M. (2009). Revisiting an engaging experience to identify metacognitive strategies towards developing a multimedia design model. *International Journal of Education and Information Technologies*, *3*(2), 115–125. ISSN 2074-1316.

Technology Acceptance of Thai Primary Student on Outdoor Learning Activity Using Mobile Device

Pradorn Sureephong, Piriyamart Sirichai and Sompon Winya

Abstract Nowadays, technology plays very important role on the learning activity. Especially, it enables the mobile learning mode, which allows the learner to get access to the knowledge anywhere and anytime. In 2013, Thailand had adopted nearly millions of tablets as a learning tool for primary school students. Although this policy brought a great change for Thai's education, the methodology to integrate the tablet into regular classroom teaching is still ambiguous for Thai's educators. Moreover, the effect of newly adopted technology on the primary school student is still under argument between technologists and educators. Hence, this research aims at analyzing the technology acceptance of 100 primary students on the mobile technology. The outdoor learning activity was set up by using the tablet as a learning tool. After the activity, the questionnaire that adopted the Technology Acceptance Model (TAM) was used for analyzing how students perceive, accept, and adopt the mobile technology to use. The result shows that student's attitude (ATT) very according to three factors [i.e., perceived of usefulness (PU), perceived ease of user (PEU), and perceived enjoyment (PE)]. Moreover, the result also shows that the behavioral intention (BI) of students on mobile learning is not affected by the attitude of the students. The comparison of the results with other related studies also confirms that the TAM of primary school student is unique and different from higher education.

Keywords Mobile learning · Technology acceptance model · Behavioral intention

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O. Sourina et al. (eds.), *Subconscious Learning via Games and Social Media*,
Gaming Media and Social Effects, DOI 10.1007/978-981-287-408-5_8

1 Introduction

Educating in the twenty-first century will become a huge phenomenon which reform the traditional teacher-centered classroom with paper-based learning to child-centered learning that more diversified learning environment to support student lifelong learning (Ministry of education 2010; OTPC project 2012). In the third-generation (3G) era, which is availability of data coverage of infrastructure and multimedia data transmission, also 3G mobile service could be used as an efficient learning tool. Thus, Thai government introduced one tablet per child policy into the primary education sector in May, 2012, namely "One Tablet Per Child (OTPC)." Tablets were used to create equality in educational opportunities and improvement between urban and rural children and also have attracted various users including teachers, educators, and administrators (Ministry of education 2010; OTPC project 2012). In Thai, schools have approximately 8 million students (Ministry of education 2010). A total of 900,000 tablets are providing around 2700 million THB. Market capacities of tablet costs would be reduced following the product life cycle so that demand for tablet usage would be increasing in the future. At this point, authors will follow up this policy by studying the effective of mobile learning as a new instructional for academician. The purpose is to enhance the understanding of the use acceptance of mobile learning. The M-learning is still in its development stage; this crucial motivational variable that will affect its adoption by user needs to be explored. The research question is to examine determinate factors relationship of Technology Acceptance Model (TAM) on mobile learning and study the behavioral intention (BI) of Thai primary student on outdoor learning activity through mobile device for the development of knowledge creatively.

2 Literature Review

The acceptance of technology has been studied actively for a couple of years. To better understanding on the methodology, these two learning theories which are mobile learning and TAM are reviewed as the background information.

2.1 Mobile Learning

Mobile learning (M-learning) is a new educational method and more flexible than previous e-learning applications (Mathieson et al. 2001). The definition of M-learning is the delivery of electronic learning content to learner utilizing mobile computing device such as tablets PC, mobile phone, and smartphone (Devaraj et al. 2002). Learner is able to access anytime and anywhere learning experiences (Gao 2005) because mobile devices allow learner to access the information outside their classroom, also able to encourage learning in the real-world context and home environment (Mobl21 2013). It is a new educational method and more flexible than previous e-learning applications (Henderson and Divett 2003). The context awareness has the potential to revolutionize the mobile social application—these new applications not only increase the profile of friends but also build new friendships. While many studies have demonstrated the benefits of applying these technologies to learning as others, authors explained that students can learn the sensing technology that can detect and record the student's behaviors in both the real and the digital world. In contrast, not all learners are similarly. Learning methodology should be adaptable to individual and divers learners, which are significant opportunities for genuine support, autonomous, and individuals learning through mobile devices (Mobl21 2013). In concern with this research, authors have studied in-depth on aspects of mobile learning such as framework, usefulness, application, evaluating, and so on and adopted M-learning as a learning tool for primary students along with the outdoor activities. This paper will support M-learning for continuously developing.

2.2 Technology Acceptance Model (TAM)

Technology acceptance can be defined as how user perceive, accept, and adopt some technology to use (Davis et al. 1989). TAM descripted the prior of the adoption of information technology (IT) and considered a strong tool for extent the adoption of new technology by users (Agarwal and Prasad 1999; Davis et al. 1989; Doll et al. 1998; Henderson and Divett 2003; Segars and Grover 1993). TAM was developed by Davis et al. (1989). TAM is derived from theory of reasoned action (TRA) as a backdrop (Ajzen and Fishbein 1980). TAM is a behavioral model that explains the antecedents of adoption of IT and is considering a robust tool for evaluating of IT by user (Davis et al. 1989). Figure 1 shows TAM which included six factors, namely external variable, perceived usefulness, perceives ease of use, attitude toward use, BI, and actual usage. It shows that user behavior was determined by perceived of usefulness (PU), perceived ease of use, and attitude (Davis et al. 1989). This study investigates the future acceptance of the emerging M-learning. In education term, use of TAMs to study technology acceptance situation would be a useful tool for understanding and managing technology initiatives. Gao (2005)

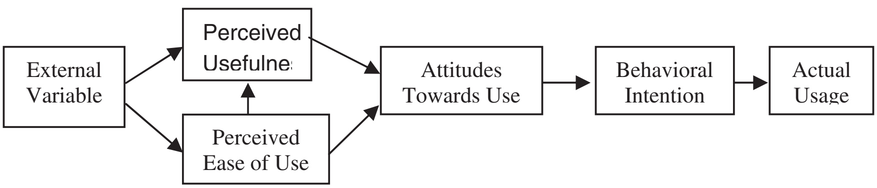

Fig. 1 Original technology acceptance model (Davis et al. 1989, p. 985)

stated that "*TAM can serve the purpose of evaluate computing products such text books, technology system and provide a valuable tool to educators.*" Therefore, this research studies adapted TAM to investigate M-learning with Thai primary student.

The following sections describe the constructs of TAM in details and relate the relationship of this study.

2.2.1 External Variable

Davis et al. (1989) observed the external variable enhances the ability of TAM to forecast future acceptance technology. However, the construct of TAM still has to extend by incorporating additional factors. The external factor chosen depends on the target of each technology study, main idea, and context (Moon and Kim 2001). In addition to more understand this study of user perception of mobile learning, two variables, namely "perceived mobility" and "perceived enjoyment," are presented in the model (Agarwal and Prasad 1999).

Perceived mobility value (*PMV*) stands for user awareness of the mobility value of mobile learning. It gains access to service information anywhere at anytime through mobile devices such as smartphone, tablets, and so on. The mobility supports user for convenience to learn when and where it is necessary. The mobility is a main advantage of M-learning. Therefore, PMV is a critical factor of individual differences affecting user's behaviors. Thus, this study uses PMV as a new variable for this TAM model.

Perceived enjoyment (*PE*) (Davis et al. 1989) is defined as the activity of using the consequences that may be anticipated. PE in this study explains that an individual finds the interaction in mobile learning as intrinsically enjoyable or interesting. It has been found to influence user acceptance significantly. Igbaria et al. (1995) and Yi and Hwang (2003).

2.2.2 Behavior Intention

Definition of behavior is a person's perceived probability that will engage in the behavior (Davis et al. 1989). BI was affected by attitude toward the behavior, subjective norm, and perceived behavioral control. The major moderator of the BI consists of four dimensions of behavior influence as following: perceived behavioral control, complexity, social desirability, and social involvement. In term of technology means that intention behavior is ready to use in technology.

3 Research Framework and Hypotheses

The research objective aims at examining the factors of students' behavior intention as shown in Fig. 2. Because Thai students have low learning intentions in the classes, their classes are still traditional teaching that teacher is the center. The mobile learning

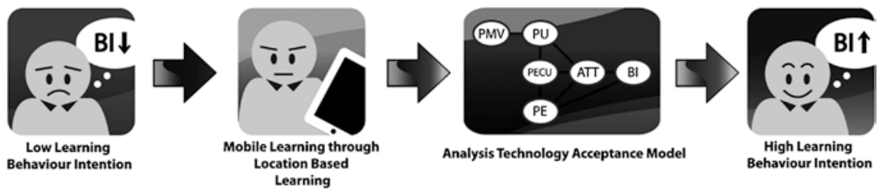

Fig. 2 Research concept

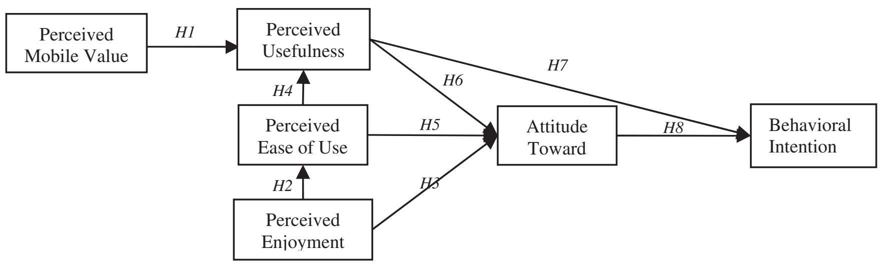

Fig. 3 Proposed extended TAM model (Davis et al. 1989 sited; Huang et al. 2006)

is a solution tool that changed traditional teaching to modern teaching through new technology. TAM investigates the factor analysis of this research concept. The outcome of the study in students will increase their high learning behavior intention in their class and accept the new media for their learning.

The causal relationship between the factors proposed original TAM from Davis et al. (1989) and also applied the proposed TAM on M-learning from Huan and Lin (2007). They increased two individual difference variables which are perceived mobility and PE. It is for more understanding of user perception of M-learning as shown in Fig. 3. On the other hand, actual usage is not a cogent measure of the value of M-learning, as indicated in previous studies (Lu et al. 2003). So, the boxes represent the factors which were measured by items and arrows representing hypotheses 1–8. In accordance with the previously stated objectives and consistent with related literature, this study tested the following hypotheses:

The mobility associated with time-related needs will encourage users to adopt mobile technology since accessibility will affect dynamic interaction and high levels of engagement. So, user who received the value of mobility also understands the uniqueness of M-learning and strong perception of its usefulness. This study treats PMV as a direct antecedence of PU.

H1 PMV has a positive effect on perceived usefulness. PE is the extent to which an individual finds the interaction of M-learning intrinsically enjoyment or interesting. Prior research role of enjoyment suggested the importance of enjoyment on users' attitude and behavior (Igbaria et al. 1995; Yi and Hwang 2003).

H2 PE has a positive effect on perceived ease of use.

H3 PE has a positive effect on attitude. The influence of perceived ease of use (PEOU) is where user feels that minimal effort is required to learn in M-learning. PU refers to the users' belief that using M-learning would help them in better learning and improve her/his performance (Davis et al. 1989). This belief creates a positive attitude toward learning, thereby increase the user's intention to use M-learning.

H4 PEOU has a positive effect on perceived usefulness.

H5 PEOU has a positive effect on attitude.

H6 Perceived usefulness has a positive effect on attitude.

H7 Perceived usefulness has a positive effect on BI. BI is the user's intention to use the M-learning to help them to perform the actual task. BI is influenced both by PU and attitude. This relationship has been examined by many prior studies (Davis et al. 1989; Venkatesh and Davis 2000).

H8 Attitude has a positive effect on BI.

4 Research Methodology

4.1 Research Framework

The research framework is illustrated in Fig. 4 on bringing knowledge testing and questionnaire validate. The authors also concentrated Thai primary students to the outdoor activities and provided the mobile learning ability through tablet. Firstly, fifteen teachers in eight core subjects were brought to the Chiang Mai Zoo to create the questions which are related to the situation location and eight core subjects. Secondly, Pre-M-learning event was studied with 30 Thai primary students from grade 4 for refining the questions. Lastly, post-M-learning event was studied with 100 Thai primary students also from grade 4, who were studying both in private and government school, by responding to the questionnaire which is based on TAM constructs validated relating to M-learning in prior research (Davis et al. 1989; Huan and Lin 2007) and then adapted to the context of the questionnaire. The participants were guaranteed confidentiality of their individual response. Before post-event, the questionnaire was assured content validity by 50 students. Authors used Cronbach's alpha (Cronbach 1951) to test the reliability of all items

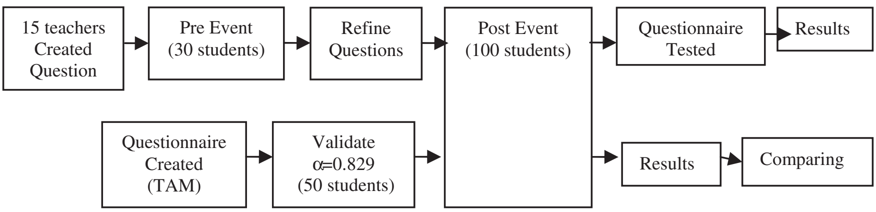

Fig. 4 Research framework

in six factors. The internal consistency of reliability coefficients in this study is well accepted because degree of reliability with statistic value is above 0.70. Later on, the questionnaire was tested by 100 students and acquired the results for discussion and conclusion in hypotheses testing. In addition, the factor analysis was conducted by LISREL to test path analysis of TAM on M-learning.

4.2 Measurement Scales

The completed instrument consisted of two sections. First section was for identifying demographic attributes of the participants. It contained demographic items such as name, year, grade, gender, and education. Second section was based on mobile learning usage and subsequently developed from TAM scales by adapted from Davis et al. (1989) and Venkatesh and Davis (2000). The questionnaire consists of 30 items that measured PMV (5 items), PEOU (5 items), PU (5 items), PE (5 items), ATT (5 items), and BI (5 items). The response scale for all items was a 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5).

4.3 Data Collection

Paper version of the mobile learning questionnaire was administrated to 100 participants to fill out all items. Thai language was used in this questionnaire to make it easier and more understandable the mobile learning questions for grade 4 Thai students. The data collected from 100 participants was analyzed to provide evidence for the validity and reliability of the questionnaire.

5 Research Results

5.1 Descriptive Statistics

The majority of the questionnaire was answered by female participants 58 % compared to the male participants 42 %. The high number of students aged was between 10 and 11 years old. The experience of mobile device usage is 74 % with device 1–2 times per week, and also its usage period was 82 % in 1–2 h per week. The factor analysis was conducted by LISREL to test path analysis. As Fig. 3 shows the relationship between the original constructs proposed (Doll et al. 1998) and the proposed TAM that includes two external variables, which are perceived mobility and PE. Moreover, the description statistics of the six factors are shown in Table 1. All means are above 4.30. The standard deviations range from 0.63 to 1.012 indicating a narrow spread around the mean. Moreover, the factors were

Table 1 Summary of means, standard deviations, and reliabilities

Factors	Measurement instrument	Mean	STD	Alpha (α)
Perceived mobility value	M-learning is my new equipment	4.43	0.868	0.722
	It is convenient to access M-learning anywhere at anytime	4.62	0.632	
	Mobility makes it possible to get the real-time data	4.37	0.747	
	M-learning able to take everywhere	4.47	0.870	
	Mobility is an outstanding advantage of M-learning	4.56	0.641	
Perceived enjoyment	M-learning would make me feel relax	4.31	0.748	0.629
	M-learning would be boring	4.37	1.012	
	I would have fun using M-learning	4.74	0.579	
	I feel excited when I learn through M-learning	4.32	0.931	
	I feel enjoy when I use mobile learning	4.56	0.729	
Perceived usefulness	It helps me do homework done faster	3.97	1.029	0.686
	Using M-learning help me to increases my scores	3.74	1.031	
	It is an advantage of my learning	4.31	0.825	
	M-learning would enhance my effectiveness in learning	4.44	0.686	
	Using M-learning would save me much time	3.95	0.999	
Perceived ease of use	My interaction with M-learning would be clear and understand	4.35	0.642	0.645
	Using M-learning would be easy to use	4.43	0.590	
	Using M-learning often, it is easy to know more about the new program	4.46	0.744	
	I know that M-learning able to do many thing	4.43	0.820	
	M-learning is easy	4.21	0.935	
Attitude	In my opinion, it would be not very desirable to use M-learning	4.50	0.882	0.465
	Learning through M-learning do not need much memories	4.41	0.726	
	I would like to use M-learning	4.87	0.367	
	M-learning made me to create more new things	4.06	0.776	
	I hold a negative evaluation of M-learning	4.56	0.925	
Behavioral intention	I want to use mobile learning both outdoor and indoor	4.72	0.637	0.772
	I want to use mobile learning each my subjects	4.38	1.013	
	I want to use mobile learning every term	4.44	0.715	
	I intend to use M-learning as much as possible	4.26	0.872	
	In the further, I intend to use M-learning routine	4.20	0.995	
Overall	**TAM**	**4.381**		**0.872**

Table 2 Assessment of discriminant validity

Factors	PE	PMV	PEOU	PU	ATT	BI
Perceived enjoyment (PE)	**1.00**					
Perceived mobile value (PMV)	0.478	**1.00**				
Perceived ease of use (PEOU)	0.196	0.584	**1.00**			
Perceived usefulness (PU)	0.332	0.495	0.440	**1.00**		
Attitude (ATT)	0.517	0.315	0.125	0.370	**1.00**	
Behavioral intention (BI)	0.273	0.423	0.313	0.341	0.258	**1.00**

analyzed using Cronbach's alpha (Cronbach 1951). The pre-questionnaire test of 50 students is 0.829. It describes that the questions are reliable and able to use for the study. All of the measure employed of 100 participants in this study demonstrated internal consistency, ranging from 0.632–0.870. The overall is 0.872. Thus, the reliability estimates ($\alpha = 0.70$) recommended by Nunnally (1967).

5.2 Discriminant Validity

This study was assessed by inspecting the correlations between the six factors as Bogozzi et al. (1991) referred. Covariance among manifest variable of the TAM is presented in Table 2 and illustrates the average variance extracted (AVE) for each factors. The questions are for each factor correlated with each other but were below for inter-correlating with other factors. Thus, the results indicate that discriminant and convergent validity of the measure are reasonable.

5.3 Hypotheses Testing

This study employed a structural equation modeling approach to develop a model that represents the relationship among the six factors such PMV, PU, PE, PEOU, ATT, and BI to use M-learning. Hypothesis testing found four of eight hypotheses were significant at 0.01 level tests. It is shown in Table 3. H1, H3, H5, and H6 were all supported. The higher the *t*-value is, the stronger the relationship is, indicating that PEOU was significantly affecting attitude ($t = 16.577$) which supports H5, whereas PE has a direct effect on attitude ($t = 12.359$), which refers H3. This result show PE factor is importance for user acceptance of a new technology (Davis et al. 1989). H1 shows PMV significantly an individual's awareness of usefulness ($t = 7.046$). It means user appreciates the value of mobility and will perceive that M-learning is useful. Moreover, PU has an effect on attitude ($t = 12.359$) that means PU is influencing their attitude of using M-learning.

The structural model and hypotheses were tested by examining the path coefficients and their significance. The path coefficients are present in Fig. 5. Consistent

Table 3 The results of hypothesis testing

Hypotheses	Path	Path coefficient	*t*-value***	Results
H1	PMV → PU	0.495	7.046**	Accepted
H2	PE → PEOU	0.508	**−0.838***	Rejected
H3	PE → ATT	0.424	14.348**	Accepted
H4	PEOU → PU	0.440	**−1.917***	Rejected
H5	PEOU → ATT	0.479	16.577**	Accepted
H6	PU → ATT	0.206	12.359**	Accepted
H7	PU → BI	0.342	**−4.481***	Rejected
H8	ATT → BI	0.242	**−17.733***	Rejected

*Significant at a 0.05 level test
**Significant at a 0.01 level test
****t*-value > 1.96 was accepted at confidential level 95 %

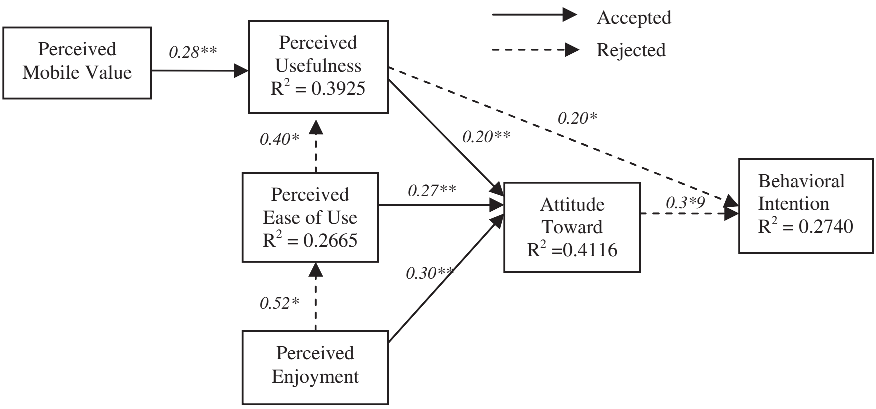

Fig. 5 Path coefficient of TAM model. *Note* R^2 represents the proportion of the variance of the variable that could be explained by its causing variable. *Significant at 0.05 level. **Significant at 0.01 level

with the hypotheses, PMV has a positive effect on PU (Path = 0.495, t = 7.046) as well as PE has a positive effect on ATT (Path = 0.424, t = 14.348), whereas PEOU and PU also have a positive effect on ATT (Path = 0.479, 0.206 and t = 16.577, 12.359). It illustrated the strength of the relationship in two multiple regression analyses (MRS) that were conducted between PMV to PU and PU to ATT. The significant factors to attitude were PU, PEOU, and PE. On the other hand, ATT was insignificant to BI. Hence, it is the difference from other research that BI was primarily affected by PU and attitude, which are critical factors (Gentry and Calantone 2002; Van der Heijden 2003).The results indicate attitude is indeed a mediator between belief and BI.

6 Discussion and Conclusion

This study examined the user's technology acceptance. The authors also found that users' attitude is directly positive affected from each 3 factors. In contrast, the hypotheses H:2, H:4, H:7, and H:8 were rejected from statistic testing, which against are previous study (Armitage and Conner 2001; US National Institutes of Health 2013; Huang et al. 2006; Davis et al. 1989). Results from correlation analysis accepted showed that PU and ATT were not significant factors in determining the intention to M-learning. This study found that the intent of students perceived is more influenced by attitude. The results also showed that users' attitude is directly positively affected by 4 factors, which are PMV, PU, PEOU, and PE, similar to Davis et al's. (1989) research that PEOU has a significant effect on ATT. It descripts that when students perceived the M-learning as one that is easy to use and nearly free of mental effort and favorable attitude toward the usefulness. The role of ATT was modest in predicting technology acceptance, and it is possible that user may use a technology even if they do not have a positive attitude toward the technology as long as it is perceived as useful and easy to use. Its concern with this study results. Yildirim (2000) also suggested that user's positive feeling toward the ease of use technology is associated with sustained use of the technology. Additional, PMV is a key of an individual's acceptance of M-learning that enables students to access learning information at anytime and anywhere. It is an important channel which provides learning material, thereby advantage of mobility is crucial to users. Thus, it could explain that 4 factors affect student's attitude in M-learning. They are easy to use, happiness, pleasure, and satisfaction from enjoyment experience (Yu et al. 2005); M-learning could enhance their learning performance (Davis et al. 1989) and recognize that mobile user valued efficiency and availability as the advantages of M-learning (Hill and Roldan 2005). However, the result is in contrast with other TAM finding that positive attitude affects BI of M-learning (Huan and Lin 2007; Jairak et al. 2009) because this research is studied primary students, but research by both Huan and Lin (2007) and Jairak et al. (2009) is studied in higher education students. It differed in age, education, and experience in sample from each study between college and primary students. So, students were from different backgrounds of digital literacy practices both in and outside school (Lyndsay Grant 2010).

This research studied both theoretical and practical contributions by developing technology-based initiative in education, analyzing, adopting, and evaluating student's learning and teaching effectiveness. The finding able to explain that the researchers, scholars, educators, or policy maker need to take into account the process of development and implementation in term of supporting perceived usefulness, PEOU, and attitude toward of primary students learning in technology to increasing BI in primary student. Furthermore, the subject of this study is primary student who are relatively homogenous as compared with the general population. Future work should conduct the testing in different population such as gender, various background, and different experiences.

Acknowledgments The authors would like to thank acknowledge Knowledge Innovation Center (KIC) at College of Arts, Media and Technology, Chiang Mai University, Thailand, for financially supporting this research, and Rockmoon Pte.Ltd for offering the Trail shuttle application and tablet devices. The authors also appreciate the help from the research team, Dr. Teeraporn Saeheaw and Ms. Boondhrikaan Vaidyanuvatti.

References

Agarwal, R., & Prasad, J. (1999). Are individual differences germane to the acceptance of new information technologies? *Decision Sciences, 30*(2), 361–391.

Ajzen, I., & Fishbein, M. (1980). *Understanding Attitudes and Predicting Social Behavior*. Englewood Cliffs, NJ: Prentice-Hall.

Armitage, C. J., & Conner, M. (2001). Committee on Communication for Behavior Change in the 21st Century, Efficacy of the theory of planned behavior, p. 31.

Bogozzi, R. P., Yi, Y., & Phillips, L. W. (1991). Assessing construct validity in organizational research. *Administrative Science Quaterly, 36*(3), 421–458. http://www.jstor.org/pss/2393203.

Cronbach, L. (1951). Coefficient Alpha and the internal structure of test. *Psychometrika, 16*, 297–334.

Davis, F. D., Bagozzi, P., & Warshaw, R. (1989). User acceptance of computer-technology—A comparison of 2 theoretical-models. *Management Science, 35*(8), 982–1003.

Devaraj, S., Fan, M., & Kohli, R. (2002). Antecedents of b2C channel satisfaction and preference: validating e-commerce metrics. *Information Systems Research, 13*(3), 316–333.

Doll, W. J., Hendrickson, A., & Deng, X. (1998). Using Davis's perceived usefulness and ease-of-use instruments for decision making: A confirmatory and multi-group invariance analysis. *Decision Sciences, 29*(4), 839–869.

Gao, Y. (2005). Applying the technology acceptance model (TAM) to educational hypermedia: A field study. *Journal of Educational Multimedia and Hypermedia, 14*(3), 237–248.

Gentry, L., & Calantone, R. (2002). A comparison of three models to explain shop-bot use on the web. *Psychology and Marketing, 19*(11), 954–956.

Henderson, R., & Divett, M. J. (2003). Perceived usefulness, ease of use and electronic supermarket use. *International Journal of Human-Computer Studies, 59*, 383–395.

Hill, T. R., & Roldan, M. (2005). Toward third generation threaded discussions for mobile learning: Opportunities and challenges for ubiquitous collaborative environments. *Information Systems Frontiers, 7*(1), 55–70.

Huan, J., & Lin, Y. (2007). Elucidating user behavior of mobile learning, a perspective of the extended technology acceptance model. *The Electronic Library, 25*(5), 585–598.

Huang, J., Lin, Y., & Chuang, S. (2006). Elucidating user behavior of mobile learning. A perspective of the extended technology acceptance model. *Electronic Library, 25*(5), 585–598.

Igbaria, M., Iivari, J., & Maragahh, H. (1995). Why do individuals use computer technology? *A Finnish Case Study, Information and Management, 29*(5), 227–238.

Jairak, K. et al. (2009). An acceptance of mobile learning for higher education students in Thailand. The sixth International Conference on eLearning for Knowledge-Based Society, 2009 (pp. 36.1–36.8). Thailand.

Lu, J., Yu, C. S., Liu, C., & Yao, J. E. (2003). Technology acceptance model for wireless internet. *Internet Research, 13*(3), 206–222.

U.S. National Institutes of Health. (2013). Behavioral Intentions, Expectations and Willingness. http://dccps.cancer.gov. Accessed on Feb 2013.

Lyndsay Grant. (2010). Connecting digital literacy between home and school. Senior Researcher, Futurelab.

Mathieson, K., Peacock, E., & Cin, W. (2001). Extending the technology acceptance model: the influence of perceived user resources. *The Data Base for Advances in Information Systems, 32*(3), 86–112.

Ministry of education. (2010). Information of the Ministry of Education. http://www.moe.go.th/data_stat. Accessed 28 Feb 2013.

Mobl21. (2013). http://www.mobl21.com/Basics_Of_Mobile_Learning.pdf. Accessed 28 Feb 2013.

Moon, J. W., & Kim, Y. G. (2001). Extending the TAM for a world wide web context. *Information and Management, 38*(4), 217–230.

Nunnally, J. (1967). *Psychometric theory*. New York: McGraw-Hill.

OTPC project (2012). http://www.otpc.in.th/aboutus.html. Accessed 20 Feb 2013.

Segars, A. H., & Grover, V. (1993). Re-examining perceived ease of use and usefulness: a confirmatory factor analysis. *MIS Quarterly, 17*(4), 517–525.

Van der Heijden, H. (2003). Factors influencing the usage of websites: the case of a generic portal in The Netherlands. *Information and Management, 40*, 541–549.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186–204.

Yi, M. Y., & Hwang, Y. (2003). Predicting the use of web-based information systems: Self-efficacy, enjoyment, learning goal orientation, and the technology acceptance model. *International Journal of Human-Computer Studies, 59*, 431–449.

Yildirim, S. (2000). Effect of an education computing course on per-service and in-service teacher: A discussion and analysis of attitudes and use. *Journal of Research on Computing in Education, 32*(4), 479–495.

Yu, J., Ha, I., Choi, M. N. D., & Rho, J. (2005). Extending the TAM for a t-commerce. *Information and Management, 42*(7), 965–976.

Ergonomic Criteria for Creating Online Educational Games for Seniors

Louise Sauve, Lise Renaud, David Kaufman and Emmanuel Duplaa

Abstract What do we know about the ergonomic criteria that are needed to create an effective online educational game for seniors? A literature review was conducted as part of a development project to flesh out a number of issues: How can game component design be adapted to accommodate seniors' physical or intellectual limitations? How should a game interface and its components be displayed on the screen to facilitate game navigation? What restrictions should be considered when selecting computer game equipment to be used by seniors? What are the guidelines for efficient game audio, video, and text readability? This chapter presents the ergonomic criteria, in terms of design, user-friendliness, and readability, used to adapt the bingo game to make it an online educational game.

Keywords Educational game · Ergonomics · User-friendliness · Design · Readability · Seniors

1 Introduction

Computer tablets and smartphones provide seniors with easy access to modern technology. The use of these devices does not require extensive technological knowledge, and if seniors are connected, they can communicate more easily

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O. Sourina et al. (eds.), *Subconscious Learning via Games and Social Media*,
Gaming Media and Social Effects, DOI 10.1007/978-981-287-408-5_9

and at any time with family and friends. The Internet has also become a source of information for connected seniors to learn about things that interest them: the weather, heath, comedy, games, gardening, etc. According to Cresci et al. (2010) and Nimrod (2011), games are top on seniors' list of such interests and are the Internet option they spend most time on.

Digital games provide seniors with many potential benefits to improve cognition and social interactions in a motivating and entertaining way, and while most studies support that statement, they also recognize that appropriate ergonomic criteria need to be defined. Starting with the basic premise that online games for seniors need to address the particular needs and physical limitations of this target group, we reviewed the literature and asked seniors to pilot test one game in order to identify ergonomic requirements for online educational games.

In this chapter, we describe the ergonomic criteria for creating an online educational game for seniors over 55 years of age in terms of design, readability, and user-friendliness. We will illustrate a concrete application of these criteria using a bingo game that was adapted to introduce learning content in order to improve seniors' quality of life.

2 Seniors and Games

The aging population represents a serious challenge for healthcare systems and social insurance in the twenty-first century. The number of people aged 60 and over is growing faster than other age groups and is expected to reach two billion in 2050 (Aalbers et al. 2011). In 2010, almost five million Canadians were over the age of 64 years. In 2036, they will number more than 10 million (HRSDC 2011).

These aging seniors are facing the decline of their physical and cognitive abilities, loss of long-term companions and social support, changes in their familial or professional environment, different lifestyles, and the increased likelihood of developing chronic and disabling diseases. But what are they doing to improve their quality of life? Can games help them effectively meet the challenges of aging?

An increasing number of studies have demonstrated that video games can have a positive impact on seniors: Digital games can provide physical training for seniors and can overcome their isolation.[1] These studies also show that the effects of these games depend on the needs and individual characteristics of seniors and that systems need to be developed that are capable of adapting to the demands of this population. An inappropriate design can act as a barrier to seniors' use of games, thus reducing the games' physical, cognitive, and social benefits and consequently seniors' health and quality of life (Whitlock et al. 2011). It is therefore important to ensure that games offered to seniors have appropriate ergonomics.

[1] Astell (2013), Dahlin et al. (2008), De Schutter (2011), Diaz-Orueta et al. (2012), Rosenberg et al. (2010).

In the case of online educational games, the ergonomist develops solutions that inform and guide the user while minimizing the cognitive and technological information load as much as possible (Barnard et al. 2013). A technology will be adopted if the person is attracted to using it, and its user-friendliness must be appropriate for the user: The technology must not be too difficult to use.

In order to establish the ergonomic indicators of online games for seniors, we rely on three quality criteria: (1) the design: The components of the game must adapt to the characteristics of the users; (2) user-friendliness: The game interface and computer equipment must be easy to use; and (3) readability: The way in which the text, illustrations, and videos are visually presented (formatting) must facilitate reading and understanding by users. We now examine how we addressed these criteria during the educational adaptation and computerization of the bingo game for seniors: "Live Well, Live Healthy!".

3 The Adaptation of the Bingo Game

Many studies have reported positive results on cognitive and physical factors, demonstrating that older adults prefer to play games which they already know.[2] One study of 932 Canadian seniors 55 years and older showed that they play board games (e.g., bingo, checkers, chess, crosswords, dart games, and scrabble), card games (e.g., freecell, poker, queen of spades, bridge, 500, Crazy Eights), and games with pieces (e.g., puzzles, Candy Crush, Tetris, Mahjong) (Kaufman et al. 2014). According to this survey, the game bingo turns out to be the most mentioned game by respondents. Figure 1 presents a description of the game. In the remainder of this chapter, we look at how the structure and content of this popular game have been adapted to create an educational online game for seniors.

3.1 Game Design

More and more studies find that it is necessary to design games specifically for the baby boomer generation, in other words, our seniors. Various aspects of the game must be adapted in terms of design[3] to create an educational game for seniors.

[2] Al Mahmud et al. (2012), Allaire et al. (2013), De Schutter (2011), Diaz-Orueta et al. (2012), Senger et al. (2012), Theng et al. (2012).

[3] De Schutter (2011), Hwang et al. (2011), McLaughlin et al. (2012), Sauvé (2010a).

Goal of the game: To be the first player to complete their card and shout Bingo.

Number of players: Variable

Games materials:
A Bingo ball cage and 75 balls, a ball board, tokens and Bingo cards with five rows and five columns. Each column is associated with a letter of the word BINGO and contains 15 randomly drawn numbers

Rules
1. All players receive a numbered card and tokens.
2. Players place a token in the center box which is free.
3. A number is announced.
4. The player places a token if the number is on their card.
5. The game can end in four ways, determined at the start of the game:
   - The player who has completed a vertical, horizontal or diagonal row of boxes and who is the first to shout "Bingo" is declared the winner.
   - The player who has completed all the boxes on their card and who is the first to shout "Covered Card" is declared the winner.
   - The player who covers all the numbers that form the contour of the card (the top and bottom rows and the columns on each side of the card) and who is the first to shout "Bingo" is declared the winner.
   - The player who covers all the numbers of the two diagonals (from one corner to the other in both directions) and who is the first to shout "Bingo" is declared the winner.

Fig. 1 Description of traditional bingo

3.1.1 Competition

The game must create competition among seniors to maintain their interest.[4] The game must (1) be short in duration (between 5 and 15 min); (2) offer a range of difficulty that takes into account player age and physical ability, and this option provides for competition between players of different ages and capacity; (3) include rules that determine the winner or winners and the loser or losers; (4) provide a scoring system that allows seniors to measure their performance; and (5) allow for gains for a positive result and losses for a negative result that will be less than the gains in order to maintain the interest of seniors who have little knowledge on the subject matter of the game.

In our "Live Well, Live Healthy!" educational game, we first determined it would take three participants or more to create competition among seniors. We gave the opportunity to vary the duration of the game by allowing players to choose how the game ends and thus decide the playing time: A complete

[4] Kickmeier-Rust et al. (2012), Marin et al. (2011), Nesta (2009), Ogomori et al. (2011), Shang-Ti et al. (2012), Theng et al. (2012), Whitlock et al. (2011).

Fig. 2 Main page interface of the game

row of vertical boxes requires less time than a full card or the contour of the card (Fig. 2b). Similarly, players choose the degree of difficulty (easy, medium, and difficult) before starting the game (Fig. 2a).

We opted to see the scoring system in the game interface at any time for each player (Fig. 3b). Then, we inserted points that reward or penalize the player according to whether they answer the question correctly or not, which in turn allows the player to place a token in one of the boxes on the card. The penalty is 50 % less than the gain in order to maintain the interest of players, in particular, for those who have little knowledge about the content to be learned. Finally, we changed the rules that determine the winners and losers in the context of an online game without a game master: The first player to click on the bingo button (Fig. 3c) after correctly placing their tokens on the bingo card wins 50 points. Players who have a "bingo" at the same time but were not fast enough to click on the "bingo" button first only receive 25 additional points. Should a player click on the bingo button and not have their tokens placed correctly, the game continues and the player loses 25 points.

3.1.2 Challenge

The game must maintain a constant challenge for the players.[5] It must introduce components that maintain a sense of uncertainty about the outcome of the game. It includes mechanisms that allow players to adapt to the game based on their

[5] Asakawa and Gilbert (2003), De Schutter (2011), Gee (2003), Lavender (2008), Marston and Smith (2012), Shang-Ti et al. (2012).

Fig. 3 Point system

capabilities (e.g., reaction time and degree of difficulty). Thus, the learning content of the game must take into account the prior knowledge of the seniors for whom it is intended, and the questions must offer varying degrees of difficulty in order to promote the participation of all players, even those with little knowledge on the subject matter at hand. Mechanisms must also be provided to ensure that the outcome of a game remains uncertain including (1) the controlled addition of random events, for example, bonus cards distributed by the computer system to reduce the gap between opponents who are sometimes too strong or too weak, and (2) the level of difficulty of the questions from one game to another.

In our "Live Well, Live Healthy!" game, we have put in place mechanisms (Fig. 2b) that allow players to choose from three levels of difficulty at the start of the game. These levels are based on the knowledge of the seniors concerning the learning content (easy, medium, and difficult) of the game (Fig. 2a). We also integrated into the game mechanics bonus balls that are drawn at random during the game, thus reducing the gap between the players that are too strong and those that are weaker (easy = 3, medium = 2, and difficult = 1).

3.1.3 Number of Players

Many studies demonstrated that it is important for seniors to play along with a partner or a family member.[6] Other studies found that social interaction and

[6] Al Mahmud et al. (2012), Brown (2012), Diaz-Orueta et al. (2012), Gerling et al. (2012), Kickmeier-Rust et al. (2012), Rice et al. (2011), Shang-Ti et al. (2012).

Fig. 4 Real-time communications tools

communications make learning easier for seniors (Cornejo et al. 2012, Wiemeyer and Kliem 2012). Mechanisms most identified are the option of playing as a team at the same computer station or of including a sound component that facilitates exchanges between players in real time during the game.

We incorporated sound and text communication tools in our “Live Well, Live Healthy!” game. A microphone is associated with each player’s avatar (Fig. 4) to facilitate real-time exchanges, and a chat space is also available for seniors who do not have access to a computer with a sound card. The chat is done in real time.

3.1.4 Game Content

To ensure effective learning, the game must incorporate learning content while maintaining a balance between learning time and play time to maintain the player’s interest (Sauvé 2010a). Learning is promoted through a variety of methods which are described in this and the next section of this paper. This content should be split up to create simple questions in order to avoid cognitive overload for the seniors.[7] The use of closed questions (true/false, multiple choice with one or more answers), sentence completion, or matching objects facilitates participation and is less demanding for seniors with memory problems. The elements of the content must be repetitive so that the senior who sees the same information reappear recognizes and considers it useful for their progression in the game. To ensure this repetition, we limit the number of questions or learning activities in the game so that they can be reused multiple times during the same game.

In our “Live Well, Live Healthy!” game, we have built a mechanism to display a question every time the number of a ball drawn at random is on a card of one or more players. If the player answers the question correctly, a token appears in the box and the player earns points (20 points for an easy question, 30 points for a medium question, and 50 points for a difficult question). If the player does not

[7] Diaz-Orueta et al. (2012), Sauvé (2010a).

correctly answer the question, the token will not appear in the box and the player loses half of the points allocated to the question. We prepared 40 questions instead of 75 (the number of balls) to ensure that these questions come at least twice during a game whose aim is to complete a full card.

3.1.5 Feedback

The game must provide feedback to support the learning of the defined content.[8] Immediate feedback, related to each learning task, allows the players to identify successful activities and those they have failed. The game must incorporate mechanisms that (1) highlight the results of each learning activity through visual or audible feedback (success or failure) such as a smiley face or sad face, positive or negative sounds, or points earned that increase a player's score; (2) correct the incorrect answers through textual, visual, or audible feedback on the content of the learning activity or provide additional information to sustain interest in the case of positive responses; and (3) allow players to see what they have learned by providing an overview of the results of the game's learning activities, together with teaching materials to review subject matter that has not been learned. The game should also provide feedback linked to players' actions throughout the game in order for players to see the results of their actions during the game. It is rare that a game is completely intuitive, so hints or a tutorial should be included to guide the player throughout the game and made available to players as needed. To make seniors comfortable with the game and reduce their cognitive load, they should be given guidance about the next action to take: Procedures and instructions must be easy to understand and, ideally, include everyday expressions and wording to facilitate the learning process. Finally, game objectives must be clearly defined and communicated to the player. The tutorial or digital assistant to guide older players should always be available with a single click. This simplifies game use by eliminating the need to quickly learn the rules of the game beforehand, thereby reducing the cognitive load. Hints, examples, and demonstrations are necessary to avoid the types of errors that reduce seniors' motivation. These should be explicit and use the imperative verb form. Game rules must also be accessible at all times in both text and sound format. Each player's and the winner's point totals should be displayed to motivate seniors to play the game again (Whitlock et al. 2011). Finally, error messages must be clear and always appear at the same place on the screen.

In our "Live Well, Live Healthy!" game, we have integrated visual feedback in the question card window (Fig. 5); it uses a smiley or sad face to communicate the results of game (A) and textual and audible feedback to explain the correct answer (B and C).

[8] Callari et al. (2012), Gerling et al. (2012), Lopez-Martinez et al. (2011), Marston and Smith (2012), Senger et al. (2012), Wu et al. (2012), Zaphiris et al. (2007).

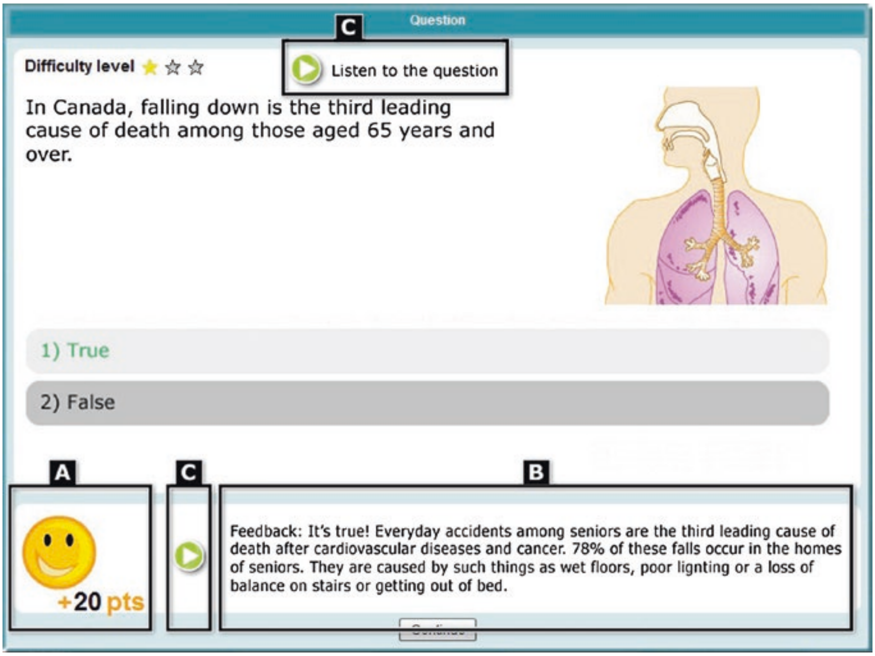

Fig. 5 Question cards

When the game is over, each senior can see their learning process in a personalized environment. Figure 6 displays questions that were not correctly answered, and information is repeated to reinforce learning content.

An accessible tutorial (Fig. 7), if needed, has been included to guide seniors throughout the game. They may at any time close or open it with a single click. We have also made available to seniors a short video that explains the flow of the game.

Our "Live Well, Live Healthy!" game displays feedback on players' performance. Figure 8 illustrates the end of a game listing each player's total points, where achievement is highlighted with the sound of applause and players are ranked according to their ability to correctly answer questions and carry out learning activities.

3.2 Game User-Friendliness

User-friendliness is the degree to which a digital game is easy and fun to use as well as understand, even by people who have little computer knowledge (Office Québécois de la langue française 2013). The purpose of the game's graphic interface is to direct the player's eye to what is important. According to Kellner (2008), a visual interface that fails to sufficiently highlight essential points is problematic. Studies have found that seniors' problems with technology use are most frequently associated with user-friendliness and could be solved by appropriate design of the

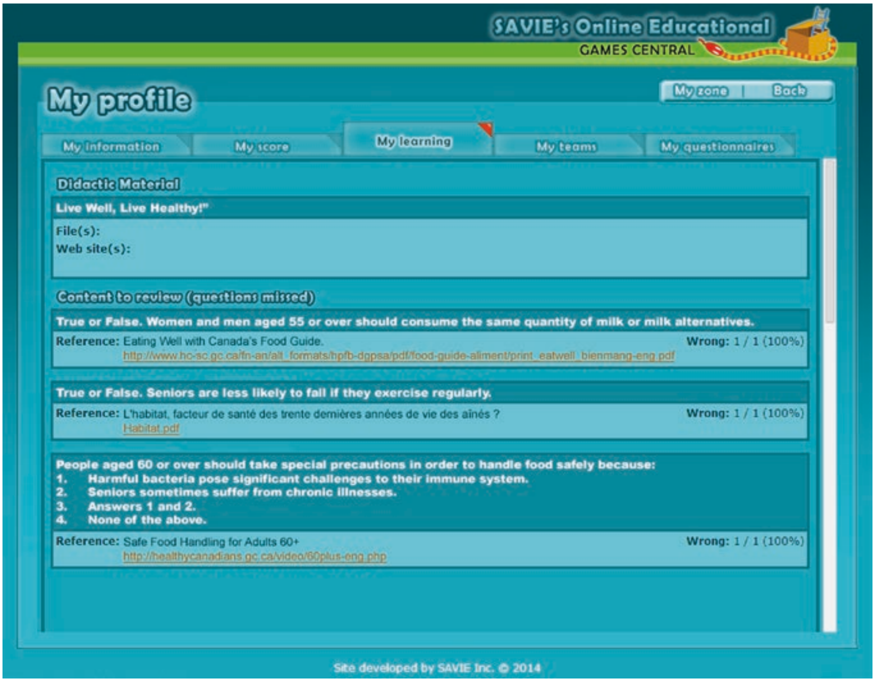

Fig. 6 Example of learning feedback

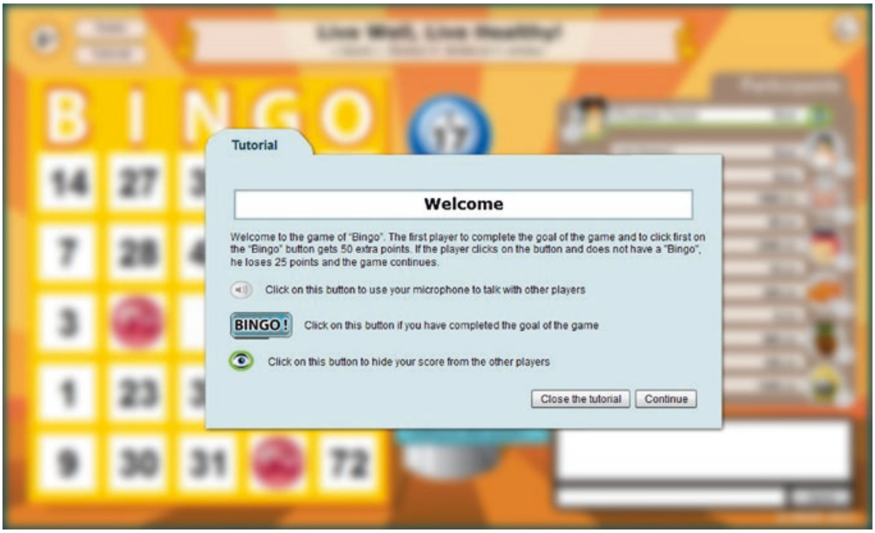

Fig. 7 Example of a tutorial

Fig. 8 End of a bingo game

screen display and game.[9] The game's user-friendliness, particularly for seniors, also depends on the type of computer equipment used. When selecting such equipment, seniors' reduced visual capacity and dexterity need to be taken into account.

3.2.1 Game Display Screen and Learning Activities

A number of parameters were identified with regard to game board design.[10] First of all, the game must use a standard screen display framework, and it is important that the game displays in the same way from one computer to another. Moreover, scroll bars should be avoided. The game display must maximize content visibility and minimize download time. The game and learning activities should also be seen in their entirety on the width of the screen without the need to use a horizontal scroll bar. Rules, tutorials, instructions, and players' scores must be in the player's field of vision and viewable on different types of computer screens. The movement of characters (avatars) or tokens in the visual environment or game board must be taken into account in order to avoid difficulty in accessing important learning information. In addition, the size of players' tokens or avatars must be in proportion to the size of the squares.

[9] Gerling et al. (2011), Hwang et al. (2011), Marin et al. (2011), Pearrow (2007), Sauvé (2010b), Whitlock et al. (2011).

[10] Chevalier (2003), Dufresne (2000), Livet (2007), Lopez-Martinez et al. (2011), Nielsen (2000), Nogier (2005), Sauvé (2010b), Shneiderman and Plaisant (2004), Whitlock et al. (2011).

In our "Live Well, Live Healthy!" game, we restricted the display size of the game board to the smallest resolution used by our target audience: 1024 × 768. For screens with larger dimensions, we inserted a background of the same color as the background of the board and programmed the display so that the board is positioned in the center of the screen. This window is always visible regardless of other superimposed windows that appear. A second window may appear superimposed onto the game board. It contains questions, answers, feedback, the tutorial, or the rules of the game. The size of this window is variable but always smaller than the board.

3.2.2 Navigation in the Game

The game should provide easy navigation and must meet certain conditions.[11] At all times, the board, tokens, navigation buttons, instructions, score, and rules must be displayed and accessible to ensure that the game runs smoothly. It is also important to consider that the repeated use of the mouse to access a game component slows the pace of the game and hinders the motivation of players. It is preferable that players access all the elements that they need with a simple click. The game must use known symbols or icons to facilitate player actions and to avoid errors due to misunderstanding. Symbols and icons must be the same on all pages of the game and located close to required actions. Finally, moving interface elements such as new windows and cascading menus should be avoided, as should games with more than three superimposed windows; these hinder the intuitiveness of the game and seniors' concentration. Like the game board, game activities and questions must be viewable without long and tedious scrolling down the screen. Players must have access to areas they need to answer using a simple click to earn points or go forward in the game. Useful game information must be conveniently placed to give the user a degree of control over the interface. Point totals and game rules should not be placed at the bottom of the page in order to keep them in the player's field of vision even if a small screen is being used.

In our "Live Well, Live Healthy!" game, we divided the game interface into three zones (Fig. 3): (A) the bingo card, rules, and tutorial; (B) information on the game's progress: the type of game, randomly drawn ball, and the bingo button for ending the game; and (C) information related to the actions of players—players' names and their scores as well as the control of the microphone and chat. All player actions are done using single clicks. We opted for buttons with words rather than symbols for ease of use by seniors who were not born in the digital age. Finally, we limited the number of superimposed windows to a maximum of two. When a second window appears in the center of the screen, the game board will be grayed out and become inactive as illustrated in Fig. 8.

[11] Barnard et al. (2013), Braun (2013), Connolly (2013), Ogomori et al. (2011), Nicolau and Jorge (2012), Pham and Theng (2012), Wu et al. (2012).

3.2.3 Controller for Playing the Game

The game console (machine) should be adjustable to the physical limitations of the players. Research studies[12] have most commonly investigated the keyboard and manual game controller. They suggest avoiding small buttons that require significant manual dexterity, as well as controllers that require a lot of manipulation because these are difficult for seniors to use. Game design should avoid double actions that require the player to precisely control a cursor on the screen while needing to correctly press a button to obtain the desired result. Controller buttons should be sensitive enough to respond to a light touch yet solid enough to support a strong hit, and large enough to be easily seen and pressed by seniors. One-handed game controllers, such as a computer mouse or a Wii controller, are preferable, as these are more accessible for seniors than those that are designed to be used with two hands. A touch interface can make interacting with the application easier; the use of a mouse requires eye–hand coordination and thus increases the cognitive load.

In our "Live Well, Live Healthy!" game, we eliminated all actions that require a double click to perform an action, whether to answer questions, to place a token on a square, or to interact with other players using real-time verbal communication tools. Since computer equipment is recommended for the game, we suggest ultralights with touch screens that allow seniors to adjust text size and images and allow moving game elements with their finger. A virtual keyboard, with an option to increase key size, facilitates the use of various game components when the screen is not touch sensitive. In this way, visual and dexterity challenges can be overcome.

3.3 Readability from Multimedia

By readability, we mean the way in which the text, illustration, or video is visually presented (formatting) in order to make reading and understanding easier for users. A readable interface is an indispensable component of any digital product (Ergolab 2003), particularly one intended for seniors. Educational games must meet certain minimum text, video, and illustration formatting criteria.[13]

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[12] Callari et al. (2012), Connolly (2013), Hwang et al. (2011), Diaz-Orueta et al. (2012), Lopez-Martinez et al. (2011), Nicolau and Jorge (2012, Ogomori et al. (2011), Pham and Theng (2012), Theng et al. (2012), Whitlock et al. (2011).

[13] See, among others: Ergolab (2003), Gerling et al. (2012), Kellner (2008), Lebrun and Berthelot (1996), Melonio et al. (2012), Millerand and Martial (2001), Nogier (2005), Sauvé (2006), Thoa (2004).

3.3.1 Text[14]

The use of larger screens improves game readability for seniors, especially if the screens are high definition. The layout of the text on the screen must facilitate reading and viewing. The text should be arranged in paragraphs, or information units, well separated for cohesion. In general, Web pages must be organized and airy, and a separation between the title of the text and paragraphs should be inserted. It is preferable that the words are seamless and the text is justified to the left to increase the speed of reading, particularly for readers with visual impairments. It is very important that the chosen font and size promote on-screen reading. The use of an easy-to-read large-size font (12 point or larger) is recommended. Some seniors with visual impairments need a 17 pt font. A mechanism or instructions must be provided to enable players to increase the font size. Reading for seniors is easier when texts are short, the quantity of information on each page is limited, and the text structure is simple. To ensure optimum readability, avoid displaying sentences entirely in upper case; lower case words are easier to read. Upper case should be restricted to the first letter of the sentence or an enumeration, or to signal a warning. They are also appropriate for brief information segments, such as the title of a button or page, or a heading. There should be a significant contrast between the text and the background, or between game layers. Finally, underlining should be restricted to for hyperlinks.

In our "Live Well, Live Healthy!" game, the text is left-justified and the only font used is Arial (12 pts for regular text and 14 pts for headings). This font is the most commonly used on the Web, as it provides users with the best readability. Upper case is only used for headings on the site to facilitate navigation. The wording used for game rules and instructions was based on principles developed by Dessaint (1995, p. 130): (1) short sentences (20–25 words, preferably a total of 80 characters); (2) one idea per sentence; (3) sentences grouped in short paragraphs (5–6 lines); (4) content written as a dialogue with the player; (5) concrete examples provided to explain a rule or instructions; (6) sentences written in the affirmative; (7) use of as few adverbs and adjectives as possible; (8) statement of objectives along with varied and simple information; and, finally, (9) placement of important words at the beginning of sentences. The vocabulary used in our rules, instructions, questions, and feedback was adapted to our target audience. Experts and our target group validated our adaptation via game trials.

3.3.2 Illustrations and Videos

The use of illustrations and videos must be relevant to the content of the game (Lopez-Martinez et al. 2011; Shang-Ti et al. 2012). Too often, games use a profusion of illustrations and videos to make their game more attractive, but these additions often lead to cognitive overload and make the display time too long, thus reducing the medium-term motivation of the players. The illustrations should not include too many

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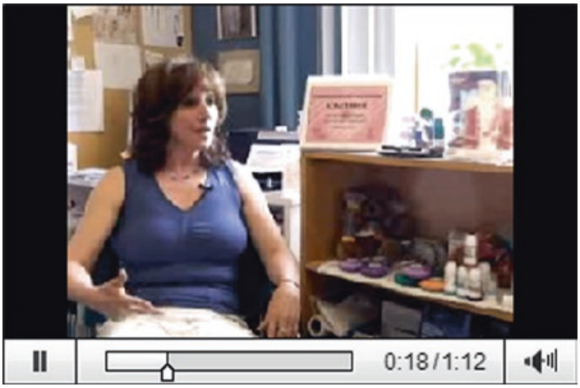
[14] Lopez-Martinez et al. (2011), Marin et al. (2011), Sauvé (2010b).

Fig. 9 Video control button



details, which would prevent players from perceiving the main idea. The positioning of the video viewer on the screen should allow for good viewing and allow access at all times to the control buttons (stop/play video, adjust volume, etc.). The displaying of an illustration or a video should not require a waiting time on the computer of more than two seconds for its appearance on screen. If this is the case and the content is relevant, it is necessary for the game to display a meter or bar that indicates the download time; otherwise, the players will think the equipment has failed. Illustrations and videos must be displayed within a window screen. If the images have too much detail or if they are large, the game should provide the option to view them in a new window. The fewest possible flashing images should be used, and animations requiring great visual acuity should be avoided, or an enlargement option should be offered to provide better visibility. Finally, recommendations are to provide seniors with clickable or movable items that are at least 2 cm (almost an inch) or larger in size.

In our "Live Well, Live Healthy!" game, we included mechanisms to facilitate the viewing of images and video capsules. Players may enlarge illustrations or videos to full screen with a simple click of the mouse (Fig. 9). We also tested the length of display time for illustrations and video capsules using various types of connection: low, medium, and high speed. Computer display time in all cases was immediate. Finally, we assessed the usefulness of each image and video illustrating game questions by the interrater method.

3.3.3 Sound[15]

Use of audio content or spoken texts can motivate seniors and increase their interest in the subject matter studied in the game (Sauvé 2010b); however, the sound samples should be used with caution. In general, it is necessary that the game offers the option to present the content in a text, in addition to the sound aspect. This is particularly true for seniors. It is important to remember that the difficulty

[15] Lopez-Martinez et al. (2011), Marin et al. (2011), Sauvé (2010b).

Fig. 10 Sound control button

of auditory information is that it fits into the flow of time, while the fixed image may remain displayed and accessible at all times. The game requires that the sound be audible and that the instructions to activate the speaker or sound controls of the computer (replay audio, adjust volume, etc.) be integrated into the game and accessible during listening. It must also allow for muting the sound in the event a player does not wish others to hear that they made a mistake. Rules and instructions relating to sound should be provided before and during the game, so the user need not return to the instructions while playing the game.

In our "Live Well, Live Healthy!" game, we integrated a virtual voice so players may listen to the questions, rules, and instructions, instead of reading them, therefore facilitating gameplay by seniors who suffer from visual impairments. Sound control is always available and associated with a button to activate or mute sound (Fig. 10), thus giving players full control over sound features.

Conclusion

"Information is part of our daily life, but it is not synonymous with simplicity. It is not enough to go on a web site to understand it, no more than it is enough to buy software to be able to make it work. They both have to be designed to be easy to use! " (Usabilis 2008:1).

Whether it is the choice of colors, fonts, organization of screen elements, navigation, or the text, visuals, or sound of a Web page, these guidelines, recommended by game and computer ergonomics experts, assure us that the GEGS and the games it generates are friendly, useful, simple, and rewarding.

When ergonomic criteria are included at the design stage, online educational games are easier to use, and thus, costs to correct problems can be avoided. In other words, good ergonomics will increase the degree to which a specific group of users are able to play a game and effectively accomplish tasks, therefore ensuring that good results are obtained to the satisfaction of users in a specific usage context. Display selection, fonts, screen element organization, navigational elements, visual, audio, and text formatting on the game interface, as well as rules and tutorials all play an important role in ensuring that the educational game is adapted to seniors' specific needs and ensure that the game environment is user-friendly, useful, simple, and motivating.

Respecting these guidelines is important in developing online applications. Delays and difficulties during the creation of online educational games can cost up to 80 percent of the project's budget to fix (Usabilis 2008). Better knowledge of effective use of a Web environment and of user needs allows us to avoid mistakes and the cost of correcting them. Reiterating the conclusions of Marin et al. (2011), it is crucial to test the ergonomics of educational games with the clientele for whom they were created. Only a formative evaluation of the educational games by seniors will allow us to measure its efficacy and ease of use, therefore contributing to optimal navigation by users.

Acknowledgments This chapter is the fruit of teamwork undertaken as part of a project funded by an Insight Grant from Canada's Social Sciences and Humanities Research Council of Canada. The goal is to examine, through the use of online games designed for seniors, the key factors for effective implementation of digital games for this audience. More specifically, our study has the following objectives: (1) develop and publicize online educational games for maintaining or adopting healthy lifestyles for retired seniors 55 years and older; (2) test these games with the target audience to check their ergonomic quality (design and user-friendliness); and (3) test these games with the target audience in order to assess the effect they have on the adoption of healthy lifestyles. We are grateful to Tatiana Signalova for her contribution to the analysis of related articles and Alice Ireland for revising the translated text. We would like also to thank the development team, under the direction of Louise Sauvé, for the online educational game: Louis Poulette, Élizabeth Parent, and Jean-François Paré.

References

Aalbers, T., Baars, M. A. E., & Olde Rickert, M. G. M. (2011). Characteristics of effective Internet mediated interventions to change lifestyle in people aged 50 and older: A systematic review. *Ageing Research Reviews, 10*, 487–497.

Al Mahmud, A., Shahid, S., & Mubin, O. (2012). Designing with and for older adults: Experience from game design, human-computer interaction. The agency perspective. Berlin: Springer.

Allaire, J. C., McLaughlin, A. C., Trujillo, A., Whitlock, L. A., Laporte, L., & Gandy, M. (2013). Successful aging through digital games: Socioemotional differences between older adult gamers and non-gamers. *Computers in Human Behavior, 29*(4), 1302–1306.

Asakawa, T., & Gilbert, N. (2003). Synthesizing experiences: Lessons to be learned from internet-mediated simulation games. *Simulation and Gaming, 34*(1), 10–22.

Astell, A. J. (2013). Technology and fun for a happy old age. In A. Sixsmith & G. Gutman (Eds.), *Technologies for active aging*. New York: Springer.

Barnard, Y., Bradley, M. D., Hodgson, F., & Lloyd, A. D. (2013). Learning to use new technologies by older adults: Perceived difficulties, experimentation behaviour and usability. *Computers in Human Behavior, 29*(4), 1715–1724.

Braun, M. T. (2013). Obstacles to social networking website use among older adults. *Computers in Human Behavior, 29*(3), 673–680.

Brown, J. A. (2012). *Let's play: Understanding the role and meaning of digital games in the lives of older adults*. Paper Presented at the Proceedings of the International Conference on the Foundations of Digital Games (pp. 273–275). New York.

Callari, T. C., Ciairano, S., & Re, A. (2012). Elderly-technology interaction: accessibility and acceptability of technological devices promoting motor and cognitive training. *Work, 41*, 362–369.

Chevalier, N. (2003). D'une démarche ergonomique pour le développement des logiciels de loisir [On an Ergonomic Process for the Development of Entertainment Softwaree]. Power Point. http://www.er.uqam.ca/nobel/r12110/pdf/6-apprentissage%20et%20feed-back.pdf. Accessed March 12, 2008.

Connolly, C. (2013). *Education programs for seniors: Aligning accessibility options with needs*. Paper presented at the Society for Information Technology and Teacher Education International Conference 2013. http://www.editlib.org/p/48803. Accessed December 5, 2013.

Cornejo, R., Hernandez, D., Favela, J., Tentori, M., & Ochoa, S. (2012). *Persuading older adults to socialize and exercise through ambient games*. Paper presented at 6th International Conference on the Pervasive Computing Technologies for Healthcare (Pervasive Health), 2012 (pp. 215–218). San Diego, CA, May 21–24, 2012.

Cresci, M. K., Yarandi, H. N., & Morrell, R. W. (2010). The digital divide and urban older adults. *Computers, Informatics, Nursing: CIN, 28*(2), 88–94.

Dahlin, E., Nyberg, L., Backman, L., & Neely, A. S. (2008). Plasticity of executive functioning in young and older adults: Immediate training gains, transfer, and long-term maintenance. *Psychology and Aging, 23*(4), 720–730.

De Schutter, B. (2011). Never too old to play: The appeal of digital games to an older audience. *Games and Culture, 6*(2), 155–170.

Dessaint, M. P. (1995). Lire, écrire et être lu [Reading, writing and readability]. In: Dessaint, M. P. (Ed.). Guide de planification de cours à distance. Québec, Canada: Presses de l'Université du Québec.

Diaz-Orueta, U., Facal, D., Herman Nap, H., & Ranga, M.-M. (2012). What Is the key for older people to show interest in playing digital learning games? Initial qualitative findings from the LEAGE project on a multicultural European sample. *Games for Health, 1*(2), 115–123.

Dufresne, A. (2000). Introduction aux principes ergonomiques [Introduction to ergonomics principles], http://lrcm.com.umontreal.ca/dufresne/bta/indexf2.html. Accessed February 3, 2006.

Ergolab. (2003). Faciliter la lecture d'informations sur le web [Facilitating the lecture with information on the web], http://www.ergolab.net/articles/faciliter-lecture-informations-web.html, Accessed October 4, 2005.

Gee, J. P. (2003). *What video games have to teach us about learning*. New York: Palgrave.

Gerling, K. M., Schulte, F. P., & Masuch, M. (2011). *Designing and evaluating digital games for frail elderly persons*. Paper Presented at the Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology, Article 62. New York.

Gerling K., Schulte F., Smeddinck J., & Masuch, M. (2012). *Game design for older adults: effects of age-related changes on structural elements of digital games* (pp. 235–242). Paper presented at The International Conference on Entertainment Computing (ICEC '12), Bremen, Germany.

Hwang, M.-Y., Hong, J.-C., Hao, Y.-W., & Jong, J.-T. (2011). Elders' usability, dependability, and flow experiences on embodied interactive video games. *Educational Gerontology, 37*(8), 715–731.

Human Resources and Skills Development Canada—HRSDC. (2011). Canadians in context—Aging population. http://www4.hrsdc.gc.ca/.3ndic.1t.4r@-eng.jsp?iid=33. Accessed April 16, 2012.

Kaufman, D., Sauvé, L., Renaud, L., & Duplàa, E. (2014). Enquête auprès des aînés canadiens sur les bénéfiques que les jeux numériques ou non leur apportent [Survey of Canadian seniors to determine the benefits derived from digital games]. Research report, Québec, TÉLUQ, UQAM, Simon Fraser University, University of Ottawa.

Kellner, C. (2008). Utiliser les potentialités du multimédia interactif [Utilizing the potential of interactive multimedia]. In: J. P. Jessel & P. Mpondo-Dicka (Eds.), Do it yourself 2.0. Comment et quoi faire soi-même à l'aide de logiciels, matériels et dispositifs numériques : de l'intérêt de la facilitation de l'action et de la production dans le monde numérique, Actes du colloque scientifique Ludovia—2008, Ax les Thermes—Ariège : Institut de Recherche en Informatique de Toulouse et Laboratoire de Recherche en Audiovisuel (pp. 160–170), Août, 27–29.

Kickmeier-Rust, M., Holzinger, A., & Albert, D. (2012). Fighting physical and mental decline of elderly with adaptive serious games. In: *Proceedings of the European Conference on Games Based Learning* (pp. 631–634).

Lavender, T. J. (2008). Homeless: It's no game—measuring the effectiveness of a persuasive videogame. Thesis Master of science, School of Interactive Arts and Technology. Canada: Simon Fraser University.

Lebrun, N., & Berthelot, S. (1996). *Pour une approche multimédiatique de l'enseignement [For a multimedia approach to teaching]*. Montréal: Collection Éducation, Éditions Nouvelles.

Livet, A. (2007). Étude sur l'évolution ergonomique des logiciels de conception [Study of the ergonomic evolution of computer design], Mémoire de première année de master en Sciences Cognitives non publié [Unpublished report for the first year of the Master's of Cognitive Science]. Université Lyon II, Bron, France.

Lopez-Martinez, A., Santiago-Ramajo, S., Caracuel, A., Valls-Serrano, C., Hornos, M. J., & Rodriguez-Fortiz, M. J. (2011). *Game of gifts purchase: Computer-based training of executive functions for the elderly*. Paper Presented at 1st International Conference on the Serious Games and Applications for Health (SeGAH), 2011 IEEE, November 16–18, 2011.

McLaughlin, A., Gandy, M., Allaire, J., & Whitlock, L. (2012). Putting fun into video games for older adults. *Ergonomics in Design: The Quarterly of Human Factors Applications, 20*(2), 13–22.

Marin, J. G., Navarro, K. F., & Lawrence, E. (2011). *Serious games to improve the physical health of the elderly: A categorization scheme*. Paper Presented at the CENTRIC 2011, The Fourth International Conference on Advances in Human-oriented and Personalized Mechanisms, Technologies, and Services. http://www.thinkmind.org/index.php?view=article&articleid=centric_2011_3_20_30056. Accessed June 20, 2012.

Marston, H. R., & Smith, S. T. (2012). Interactive videogame technologies to support independence in the elderly: A narrative review. *Games for Health Journal, 1*(2), 139–152.

Melonio, A., Tarantino, L., & Mascio, T. (2012). Towards ICT support for elderly displaced people: looking for natural gestures. In M. De Marco, D. Te'eni, V. Albano, & V. Za (Eds.), *Information systems: crossroads for organization* (pp. 135–143). Management, Accounting and Engineering: Physica-Verlag HD.

Nesta. (2009). Preparing for ageing. http://www.nesta.org.uk/library/documents/prepare-for-ageing-v14.pdf. Accessed June 13, 2010.

Millerand, F., & Martial, O. (2001). Guide pratique de conception et d'évaluation ergonomique de sites Web [Pratical guide to the design and evaluation of Web sites], Centre de recherche informatique de Montréal, http://www.crim.ca/files/documents/services/rd/GuideErgonomique.PDF. Accessed June 12, 2005.

Nicolau, H., & Jorge, J. (2012). *Elderly text-entry performance on touchscreens*. Paper Presented at the Proceedings of the 14th international ACM SIGACCESS Conference on Computers and accessibility (pp. 127–134). New York, doi>10.1145/2384916.2384939.

Nielsen, J. (2000). *Designing web usability, the practice of simplicity*. Indianapolis, IN: New Riders Publishing.

Nimrod, G. (2011). The fun culture in seniors' online communities. *The Gerontologist, 51*(2), 226–237.

Nogier, J. F. (2005). Ergonomie du logiciel et design web. Le manuel des interfaces utilisateur [Computer ergonomics and weh design: The manuel of user interfaces]. Paris: Collection InfoPro, Dunod.

Office québécois de la langue française. (2013). Convivialité [User-friendliness]. Le grand dictionnaire terminologique. http://gdt.oqlf.gouv.qc.ca. Accessed November 24, 2013.

Ogomori, K., Nagamachi, M., Ishihara, K., Ishihara, S., & Kohchi, M. (2011). *Requirements for a cognitive training game for elderly or disabled people*. Paper Presented at International Conference on the Biometrics and Kansei Engineering (ICBAKE), September 19–22, 2011.

Pearrow, M. (2007). *Web usability handbook* (2nd ed.). Boston, MA: Charles River Media.

Pham, T. P., & Theng, Y.-L. (2012). *Game controllers for older adults: Experimental study on gameplay experiences and preferences*. Paper Presented at the Proceedings of the International Conference on the Foundations of Digital Games (pp. 284–285). New York.

Rice, M., Wan, M., Foo, M.-H., Ng, J., Wai, Z., Kwok, J., Lee, S., & Teo, L. (2011). *Evaluating gesture-based games with older adults on a large screen display*. Paper Presented at the Proceedings of the 2011 ACM SIGGRAPH Symposium on Video Games (pp. 17–24).

Rosenberg, D., Depp, C. A., Vahia, I. V., Reichstadt, J., Palmer, B. W., Kerr, J., et al. (2010). Exergames for subsyndromal depression in older adults: A pilot study of a novel intervention. *American Journal for Geriatric Psychiatry, 18*(3), 221–226.

Sauvé, L. (2006). *Guide de rédaction d'un devis de conception: quelques règles médiatiques [Guide for writing a design plan: Media rules]*. Québec: SAVIE.

Sauvé, L. (2010a). Effective educational games. In D. Kaufman & L. Sauvé (Eds.), *Educational gameplay and simulation environments, case studies and lessons learning* (pp. 27–50). New York: IGI global, Hershey.

Sauvé, L. (2010b). Usabililty guidelines for a generic educational game shell. In D. Kaufman & L. Sauvé (Eds.), *Educational gameplay and simulation environments, case studies and lessons learning* (pp. 27–50). New York: IGI Global, Hershey.

Senger, J., Walisch, T., John, M., Wang, H., Belbachir, A., Kohn, B., et al. (2012). Serious gaming: Enhancing the quality of life among the elderly through play with the multimedia platform silver game. In R. Wichert & B. Eberhardt (Eds.), *Ambient assisted living* (pp. 317–331). Berlin, Heidelberg: Springer.

Shang-Ti, C., Huang, Y. G. L., & Chiang, I. T. (2012). *Using somatosensory video games to promote quality of life for the elderly with disabilities*. Paper Presented at IEEE Fourth International Conference on the Digital Game and Intelligent Toy Enhanced Learning (DIGITEL), March 27–30, 2012.

Shneiderman, B., & Plaisant, C. (2004). *Designing the user interface: Strategies for effective human-computer interaction* (4th ed.). Boston, MA: Addison Wesley.

Theng, Y.-L., Chua, P. H., & Pham, T. P. (2012). *Wii as entertainment and socialisation aids for mental and social health of the elderly*. Paper Presented at the Proceedings of the 2012 ACM Annual Conference Extended Abstracts on Human Factors in Computing Systems Extended Abstracts.

Thoa, E. (2004). Ergonomie et jeu vidéo [Ergonomics and video games] http://www.usabilis.com/articles/2004/ergonomie-jeu.htm. Accessed April 12, 2008.

Usabilis. (2008). Ergonomie informatique [Information ergonomics]. http://www.usabilis.com/methode/ergonomienformatique.htm. Accessed December 12, 2008.

Whitlock, L. A., McLaughlin, A. C., & Allaire, J. C. (2011). Video game design for older adults: usability observations from an intervention study. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 55*(1), 187–191.

Wiemeyer, J., & Kliem, A. (2012). Serious games in prevention and rehabilitation—a new panacea for elderly people? *European Review of Aging and Physical Activity, 9*(1), 41–50. doi:10.1007/s1556-001-0093-x.

Wu, Q., Miao, C., Tao, X., & Helander, M. G. (2012). *A curious companion for elderly gamers*. Paper Presented at the Network of Ergonomics Societies Conference (SEANES), 2012 Southeast Asian (pp. 1–5). Langkawi, Kedah, July 9–12. doi:10.1109/SEANES.2012.6299597.

Zaphiris, P., Kurniawan, S., & Ghiawadwala, M. (2007). A systematic approach to the development of research-based web design guidelines for older people. Journal Universal Access in the Information Society archive, 6(1): 59–75, doi:10.1007/s10209-006-0054-8.

EEG-Based Serious Games

Olga Sourina and Yisi Liu

Abstract Recently, new types of sensors such as electroencephalogram (EEG) devices became available for game development. This makes possible to adapt games using brain states recognition, for example, emotion recognition from EEG or to propose neurofeedback games. In this work, real-time emotion recognition and fractal dimension-based neurofeedback algorithms are implemented and integrated in serious games. Two types of serious games are designed and implemented: e-learning and neurofeedback games. Emotion-enabled e-learning games such as emotional companions and "Bar" game and neurofeedback games such as "Escape," "Shooting," "Affective shooting," "Maze," and collaborative "XEE" games are described.

Keywords Serious games · EEG · Adaptive interfaces · Emotion recognition · BCI · Neurofeedback · Affective computing

1 Introduction

Different from digital commercial games, serious games are developed for learning and behavior changing (Connolly et al. 2012). In (Alvarez et al. 2007), serious games are categorized into 5 types: edutainment, advergaming, edumarket, political, and training and simulation games. The edutainment games make the learning process entertaining, for example, e-learning games can be considered as edutainment serious games; the advergaming games include different types of advertisements in the game such as car logos in a race game; the edumarket games combine various goals in the games such as advertising, political, and education; the

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O. Sourina et al. (eds.), *Subconscious Learning via Games and Social Media*,
Gaming Media and Social Effects, DOI 10.1007/978-981-287-408-5_10

Fig. 1 The categories of serious games

political/business games have a political/business situation, for example, the player acts as the president of a nation or manager of the company; the training and simulation games are used to train and exercise different skills. Besides these 5 types of serious games, there are also games for medical applications such as rehabilitation games (Rego et al. 2010), for example, games for stroke rehabilitation (Hou and Sourina 2013), and neurofeedback games, for example, for the treatment of children with attention deficit disorder (ADD) (Fuchs et al. 2003). As the political/business games could be considered as situation simulation games, serious games generally can be classified into 5 types: training and simulation games, edumarket games, edutainment games, advergaming, and medical games as shown in Fig. 1.

In this work, we introduce and describe EEG-based serious games such as medical games and edutainment games. EEGs stands for electroencephalograms which are the brain waves of human. It is a noninvasive technique to measure the human brain activity in real time. We propose and describe EEG-based e-learning games that are related to edutainment games and neurofeedback games that are related to medical once. In the case of e-learning games, the EEG-based technology aims at making the games more adaptive and immersive, and in the case of medical games, it aims to help treating the psychological disorders or to improve cognitive abilities of healthy people.

As it is stated in Boyle et al. (2011), the active, situated, and problem-based learning with immediate feedback can make the learning more effective, and the e-learning game can be adapted to the user's experience, knowledge, or even the user's internal feelings to optimize the learning experience. The recognized emotions of the player can help make the learning procedure more complete, more engaging, less stressful, or more stressful depending on the target of the game. The player's emotions can be recognized based on audio input such as the word choices (Lee and Narayanan 2005) and prosody (Truong and van Leeuwen 2007) in speech, or based on visual input such as facial expressions (Tong et al. 2007) and gestures (Gunes and Piccardi 2005) in videos, or biosignals including EEG signals. Emotion recognition from facial expression and from vocal expression have a relatively long history which can be traced back to 1978 (Suwa et al. 1978) and 1972 (Williams and Stevens 1972); however, there are still some unsolved problems in these approaches to recognize emotions. For example, most of the studies focus on the recognitions of the basic emotions such as happiness, sadness, or anger; recognition needs to be able to differentiate between deliberate and spontaneous facial expressions or vocal input; and the recognitions are mostly context dependent (Zeng et al. 2009). On the other hand, EEG is the technology used in brain computer interface (BCI) systems to detect the brain states of the user and can be applied in games. For example, mental states such as the user's emotions, concentration levels, or motor imagery can be recognized from EEG signals in real time and serve as an additional game control to modify the game difficulty levels (Chanel et al. 2011), to change a character's appearance (Sourina et al. 2011) (Wang et al. 2010), to reflect the user's emotions on his/her avatar (Liu et al. 2010), or even to change the plot of the game (Lecuyer et al. 2008; Coyle et al. 2011). EEG-based emotion recognition has unique advantages over other emotion recognition techniques: It has high temporal resolution (Lin et al. 2010; Petrantonakis and Hadjileontiadis 2012), and it can reflect the true inner feelings of the users (Nie et al. 2011). Even if the user does not have any explicit facial expressions or say nothing, his/her emotional states can be recognized by using EEG signals (Aspiras and Asari 2011).

The combinations of different bio-signals are used in e-learning games with emotion recognition (Shen et al. 2009). However, little has been done on emotion recognition through EEG signals only. Currently, the EEG devices are wireless, more portable, wearable, and easy to use, which allows more research to do on real-time emotion recognition algorithms.

In neurofeedback games, EEG is used to measure the brain state of the player and corresponding feedback is given to the user with a visual or auditory stimuli. If the brain activity is in a desired way, the player will receive a reward in the game (Nijholt et al. 2009). This kind of game can be used as the treatment for patients with psychological disorders. The brain patterns of these patients are different from healthy people, and neurofeedback games are designed to regulate these abnormalities. The games can also be used to improve cognitive abilities of healthy people. For example, the music performance (Egner and Gruzelier 2003) and dance performance (Raymond et al. 2005) are improved after neurofeedback training.

In our work, we proposed to use a real-time emotion recognition algorithm for e-learning games and fractal dimension algorithm for neurofeedback games. Different types of e-learning games and neurofeedback games are designed and implemented.

2 Review on Adaptive Emotion-Enabled E-Learning Games

In recent years, more and more researchers and game developers realize an importance of adaptive e-learning games. It is possible to adapt games to the user by avoiding undesired emotions and by eliciting/maintaining the targeted emotions in the game. Adaptive games in education such as e-learning games can optimize the user's experience and improve efficiency of the games.

Generally, the user's emotions can be defined based on the answers to a questionnaire or during an interview. However, in interactive games, reporting is not a proper technique since it would interrupt the user's game experience and can be done only after the game to validate the results obtained by overt behavior or physiological measurement (Tijs et al. 2008). Tsai et al. (2012) is one of the examples where overt behavior is used to adapt the difficulty level in e-learning games. In Tsai et al. (2012), facial expressions were recorded by Webcam, and the corresponding emotions were recognized to adjust the difficulty level in the game-based adaptive learning system. It was confirmed that the usage of emotions in adapting the game-based learning system could benefit the user by improving his/her learning motivation.

The advantage of recognition from overt behaviors such as facial expressions or button pressure is that the player does not need to put on any devices. However, such algorithms have difficulty differentiating between deliberate and spontaneous emotions. Also, most of the studies focus on the recognitions of basic emotions such as happiness, sadness, or anger only.

Compared with the above-mentioned technologies, the use of EEG in the emotionally adaptive games is still a new topic and needs more investigation. However, EEG-based emotion recognition has unique advantages over other emotion recognition techniques: It has high temporal resolution; it can recognize more emotions; it is non-invasive and easy to use; and it can reflect the inner and true feelings of the users. This technology can be used in the emotionally adaptive games to make them more intelligent. Some pilot studies have supported this claim, for example, (Nacke et al. 2011) has found that EEG can be used as an affective ludology measure to assess the game playing experience. Chanel et al. (2011) tried to adapt the difficulty level of Tetris games based on the users' emotional states. Three emotions were recognized from EEG in Chanel et al. (2011), and the best accuracy of 56 % was obtained to recognize boredom, anxiety, and engagement.

Although the use of EEG in games is in its early stage, it shows its potential to help the user become more immersed in the games and have an overall better experience since the game can be adapted without interrupting the game experience.

3 Review on EEG-Based Neurofeedback Games

The EEG-based neurofeedback games can be used for patients with mental disorders such as ADD, general anxiety disorder, and substance use disorder as a treatment.

In neurofeedback games, visual feedback such as color, audio feedback, or velocity change of the objects can be used to indicate whether the current brain state expected to be inhabited or rewarded. For example, car racing neurofeedback game was implemented in Pope and Bogart (1996). In this game, a car's maximum speed is positively related to the attention level of the player. If the player is more attentive, he/she can drive faster. A pacman maze game was implemented in Fuchs et al. (2003). The game is used as the treatment for children with attention deficit/hyperactivity disorder, and the training protocol is to increase power of sensorimotor rhythm (SMR, 12–15 Hz) and beta1 bands (15–18 Hz) and to decrease power of theta (4–7 Hz) and beta2 bands (22–30 Hz) of the player. If the power in the reward EEG bands increases, the icon in the game is moving faster and becomes brighter. If the power in the inhibit bands increases, the icon stops moving and becomes black. Clarke et al. (2001) analyzed the brain activity of ADD patients and compared with healthy people. It is found that the theta/beta ratio of the ADD patients is larger than in healthy people. Based on this finding, the neurofeedback protocol includes decreasing activity in the theta band and increasing activity in the beta band (or decreasing theta/beta ratio) (Clarke et al. 2001; Lubar 1995).

Neurofeedback games can also be used to enhance cognitive abilities of healthy people. In such neurofeedback games, different neurofeedback protocols are applied. For example, in Thomas et al. (2013), a game was proposed to improve the attention and memory skills of healthy people. It requires the player to memorize the numbers in a matrix and then to fill the matrix with the help of attention level recognized from EEG signals: He/she can select the answers only when his/her attention level is high enough. The sample entropy feature is used to measure the attention level; as it is found that when people have high concentration, the values of sample entropy is larger than when people have low concentration state. It concludes that the performance is improved significantly after playing the games. In Heinrich et al. (2007), the player needs to modulate his/her brain activity in order to make the mouse successfully vault the rod. The subjects need to modulate their slow cortical potentials. In Hanslmayr et al. (2005), subjects are trained to increase the individual upper alpha power. Besides the individual upper alpha power, subjects are also trained to decrease their theta power in Zoefel et al. (2011). In both Hanslmayr et al. (2005) and Zoefel et al. (2011), it is shown that after the neurofeedback training, the performance of the subjects in mental rotation tasks is improved. In Escolano et al. (2011), when the upper alpha is increased, it shows that the working memory is improved after training. By raising the theta/alpha ratio, the music performance (Egner and Gruzelier 2003) and dance performance (Raymond et al. 2005) are improved. Another method of the neurofeedback training for healthy people is based on sensorimotor rhythm (SMR) which ranges from 12 to 15 Hz (Vernon et al. 2003). The cognitive performance is improved after 8 sessions of neurofeedback training to increase SMR/theta and SMR/beta ratios. In Egner and Gruzelier (2001), the target of the neurofeedback training is to increase the SMR band power, and it shows that the commission errors are reduced and perceptual sensitivity on a continuous performance task is improved.

4 EEG-Based Game Design

In this work, we propose and describe EEG-enabled serious games. In all our games, we use 14 electrodes Emotiv device (Emotiv) to obtain EEG signals. The locations of the electrodes are standardized by the American Electroencephalographic Society (American Electroencephalographic Society 1991), which include AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4. The technical parameters of the device are as follows: bandwidth—0.2–45 Hz, digital notch filters at 50 Hz and 60 Hz, A/D converter with 16 bits resolution, and sampling rate of 128 Hz. The data are transferred via wireless receiver. Figure 2 gives an example of the subject wearing the Emotiv device.

The diagram of the EEG-enabled game is illustrated in Fig. 3. The game consists of two parts: signal processing and the game flow. In the signal processing part, the EEG signals are acquired by EEG device and filtered by the artifact removal methods such as bandpass filter and then, the data are passed to a brain state recognition algorithm. In the algorithm, features are extracted from the

Fig. 2 Subject with Emotiv device

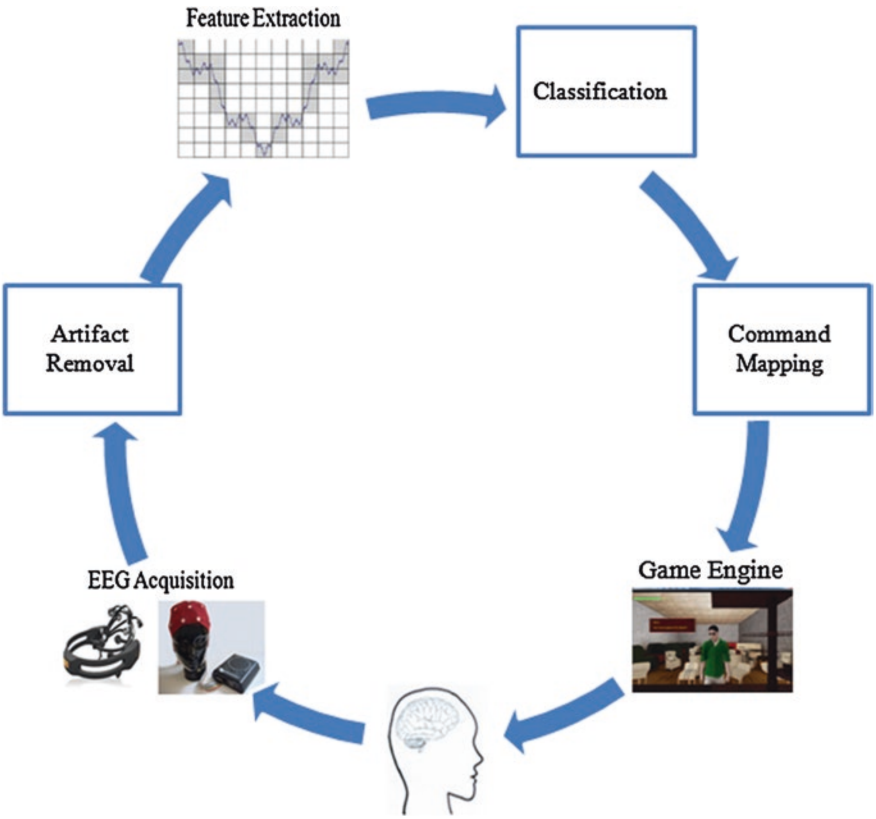

Fig. 3 Diagram of the EEG-based game

filtered data and fed into the classifier such as support vector machine or the features are compared with thresholds. Then, the recognized brain state is send to the game part by a TCP sender. In the game part, the UDK game engine is used to implement the games. After receiving the recognized brain state from the TCP sender, the corresponding command is triggered in the game based on the recognized brain state. For example, in e-learning games, the command can be the decision on the difficulty level in the next round. In neurofeedback games, the command can be, for example, changing the background or target colors to tell the player whether his/her current brain state is the desired or undesired one.

5 Emotion-Enabled E-Learning Games

EEG-based emotion recognition algorithms can be divided into two types: subject dependent and subject independent. A system training session for each individual player should be implemented when the subject-dependent algorithms are used.

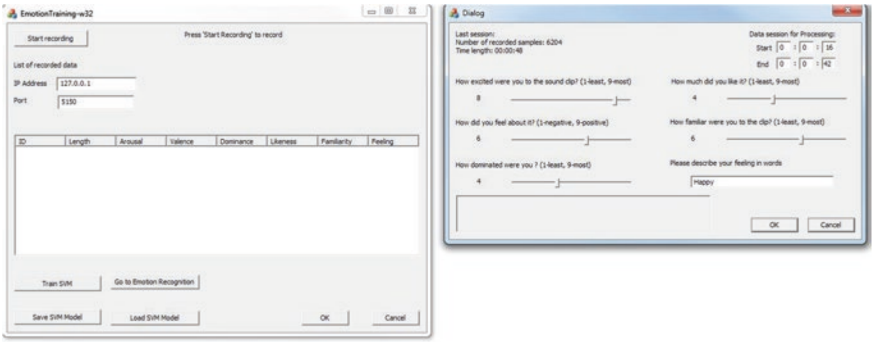

Fig. 4 The screenshot of the real-time emotion recognition system with training session

As a result, a better accuracy than with subject-independent algorithms can be obtained in the case of subject-dependent algorithms. To make the e-learning game emotion-enabled, a real-time emotion recognition system with training is implemented based on the subject-dependent emotion recognition algorithm proposed in Liu and Sourina (2013). In the proposed algorithm, fractal dimension in combination with statistical and higher order crossings is used as feature, and the support vector machine with polynomial kernel is used as the classifier. As the proposed algorithm is a subject-dependent one, a short training which lasts around 5 min is needed. During the training session, audio stimuli from IADS database (Bradley and Lang 2007) are used to evoke emotions. The EEG signals are recorded during the exposure of the user to the sound stimuli. Then, a panel for the subject is popped up to rate the feelings as shown in Fig. 4. The recorded session with the subject's rating is saved and shown in the main panel of the emotion recognition system as shown in Fig. 5. After EEG for training is recorded, a SVM classifier is trained and saved, which is used in the real-time emotion recognition.

With the help of the real-time emotion recognition system, different emotion-enabled e-learning games such as emotional companions (Sourina and Liu 2013) and a bar game (Sourina and Liu 2014) are designed and implemented. The first type of e-learning games is the emotional companion. The emotional companion can make the e-learning system more immersive and interactive. Different emotional companions are designed and implemented including "Emotional avatar" and "Twin girls." In Fig. 6, the "Emotional avatar" is shown. Here, the Haptek 3D avatar (Haptek) is integrated with the emotion recognition algorithm. The facial expressions of avatar are changed based on the recognized emotion of the user. As can be seen from Fig. 6, the current emotion state of the subject is "pleasant." In Fig. 7, the "Twin girls" is shown. The girls' hair color, dressing code, facial expressions, and behaviors are changed according to the current emotion state of the user. The example in Fig. 7 shows that the recognized emotion of the user is "happy," so the girl twins' hair color and dress become pink, their facial expressions are smiling, and their dance movements express happy emotion.

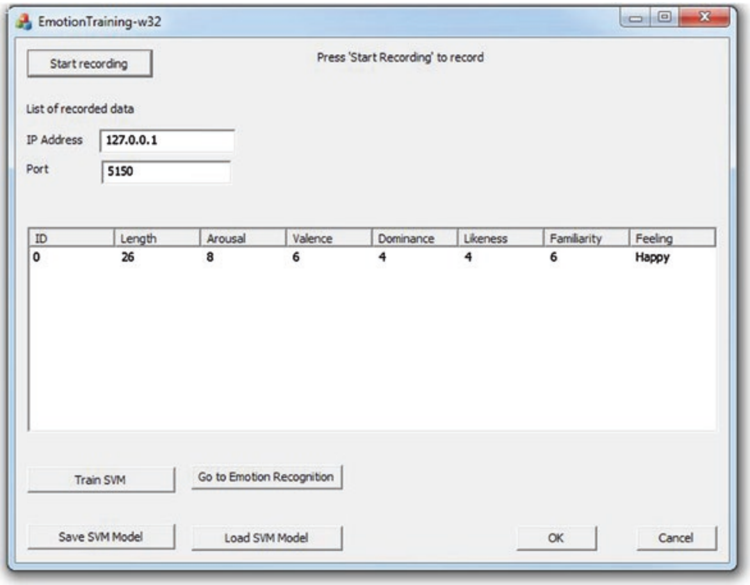

Fig. 5 The screenshot of the main panel of the emotion recognition system

Fig. 6 Emotional avatar with pleasant emotion

The second type of e-learning games is a "bar game" as shown in Fig. 8. This game targets at training the ability of the player's memorization. During the game, the player acts as a bartender, and he/she needs to remember the customers' names and the corresponding orders of drinks. The game is designed and implemented with three difficulty

Fig. 7 "Twin girls" with happy emotion

Fig. 8 "Bar" game

levels. In the first difficulty level, only first names of the customers and the ordered drinks have to be remembered. In the second difficulty level, first and family name of the customers and the orders need to be memorized. In the third difficulty level, names from different cultures have to be remembered. The difficulty level of the next round is decided by the name–order mapping result and the dominant emotions of the current round. For example, if the player correctly maps the names and orders, and the emotion recognized in the current round is positive, then the difficulty level of the next round is increased to make the game more challenging. If the player wrongly maps the names and orders, and the emotion recognized in the current round is negative, then the difficulty level of the next round is decreased to avoid the player feeling frustrated. The difficulty level of the next round remains unchanged if the player feels negative and does the correct mapping or if the player feels positive and does the wrong mapping.

6 Neurofeedback Games

A neurofeedback system is implemented based on the algorithm proposed in Wang et al. (2011). In the proposed neurofeedback algorithm, fractal dimension is extracted from EEG signals in real time as a feature and is compared with thresholds to quantify the concentration level of the user. The screenshot of the implemented neurofeedback system is given in Fig. 9. Besides the novel fractal dimension-based neurofeedback algorithm, traditional power-based algorithms are also implemented. The users can train the alpha, beta, theta, delta, and beta/theta ratio or even define the frequency band to be trained by them. The user can select the training protocol in which a certain brain activity pattern is inhabited or reinforced. For example, if the neurofeedback training targets to increase the alpha power, the reinforced mode should be chosen. In this case, the reward command in the games is triggered only when the value of alpha power calculated in real time is

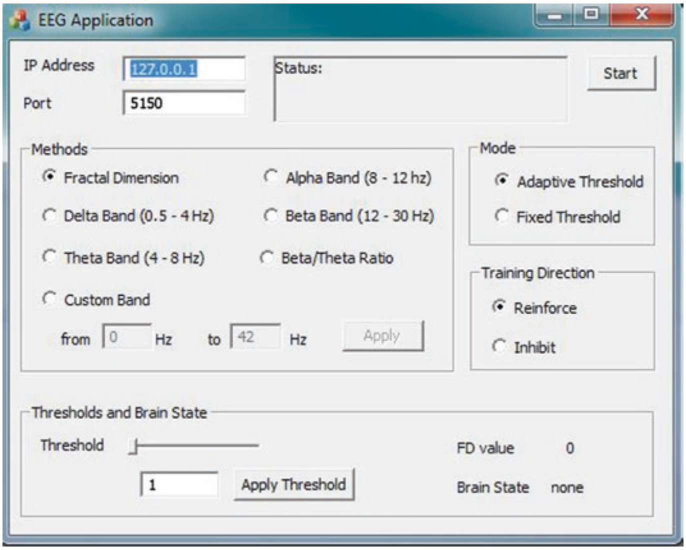

Fig. 9 Screenshot of the implemented neurofeedback system

larger than the threshold. If the neurofeedback training targets to decrease the theta power, the inhibit mode should be chosen. In such case, the reward command in the games is triggered only when the value of theta power calculated in real time is smaller than the threshold. The thresholds can be fixed or adaptive. If the adaptive threshold is selected, the threshold would gradually increase or decrease according to the subject's performance. For example, when the adaptive threshold mode is chosen, if the FD values or power values computed from the subject's EEG cannot exceed the threshold for a long time, the threshold will be decreased automatically.

With the implemented FD-based neurofeedback system, the neurofeedback games including "Escape" (Wang et al. 2011), "Shooting" (Sourina et al. 2012), "Affective shooting" (Sourina and Liu 2013), "Maze," and collaborative "XEE" game are designed and implemented in our work.

In the "Escape" game, the player needs to escape from a number of locked rooms. However, the password to open the door of each room is unknown. The player has to use his/her brain power (concentration level) to activate the locker and get the password as shown in Fig. 10. There is also a time limit in the game, which means the player has to concentrate to get the password and enter the room where a car to escape is parked within the given period.

In the "Shooting" game, the player needs to shoot all targets in the palace to win the game as shown in Fig. 11. There are lamps on the targets, and the color of the lamps is changed based on the concentration level recognized by the neurofeedback algorithm. If the recognized brain state of the player is concentrated, the lamps on the targets turn blue and the targets disappear after the player shoots them. If the player is inattentive, the lamps on the targets are red and they do not disappear after the player shoots them.

In the "Affective shooting" game, the emotion recognition is added to the neurofeedback games. This game is used to train the player to maintain a positive and concentrated state. In the game, the player needs to shoot all targets such as apples and statue in a limited time as shown in Fig. 12. For example, when the

Fig. 10 "Escape" game

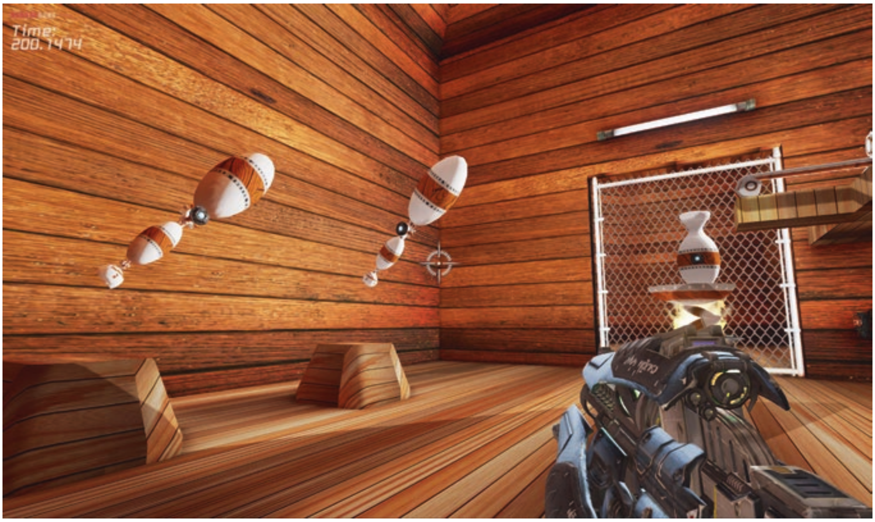

Fig. 11 “Shooting” game

Fig. 12 “Affective shooting” game

recognized brain state is positive and highly concentrated, the background color is green and the targets move following the default setting; when the recognized brain state is positive and not concentrated, the background color turns blue and the targets move faster to induce higher concentration; when the recognized brain state is negative and highly concentrated, the background color turns orange and the targets move slower to ease the player and induce positive emotions; when the

Fig. 13 “Maze” game

recognized brain state is negative and not concentrated, the background color turns red to induce positive emotion and the player cannot shoot the targets until he/she concentrates.

In the “Maze” game, the player needs to collect keys in the maze to gain points as shown in Fig. 13. However, there are boxes which block the way in the maze. In the game, a keyboard and mouse are used to move forward and navigate the walking direction. The concentration level recognized from EEG is used to push the boxes away. Two difficulty levels are designed and implemented in this game. At the first difficulty level, the player just needs to push the box away; then, he/she can walk freely. In the second difficulty level, the player needs to push the box to the specified location; otherwise, the path is still blocked even if the box is pushed aside.

In the collaborative “XEE” game, up to three players can play the game simultaneously. Several fences appear on the way, and the players need to concentrate to make fences vanished as shown in Fig. 14. Different players have different timings for removing the gates, and the final score is based on the combined effort. For example, if all players have high concentration, they can make the fences to vanish immediately, and the total time of all players to complete the game is short. In such case, a golden medal is given. Otherwise, a silver or bronze medal is issued based on the overall time of all players to complete the game.

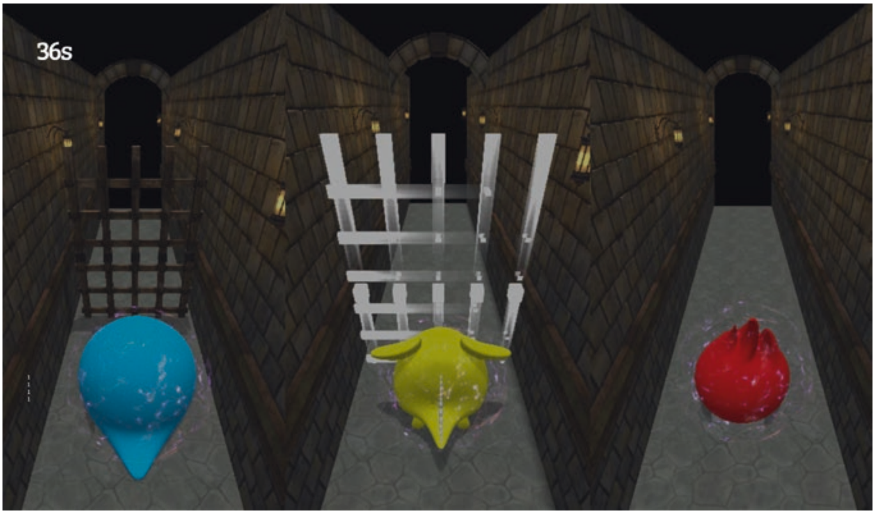

Fig. 14 Collaborative "XEE" game

7 Conclusion

In this work, we presented the review on EEG-based serious games and described proposed emotion-enabled e-learning games and neurofeedback games. Novel real-time EEG-based emotion recognition and fractal dimension-based neurofeedback algorithm are used in the game development. Emotion-enabled e-learning games such as emotional companions and "Bar" game and neurofeedback games such as "Escape," "Shooting," "Affective shooting," "Maze", and collaborative "XEE" games are implemented and described. The next step of the project is to test these games on subjects and asses its effectiveness in e-learning and medical applications.

Acknowledgments This research was done for Fraunhofer IDM@NTU, which is funded by the National Research Foundation (NRF) and managed through the multi-agency Interactive & Digital Media Programme Office (IDMPO) hosted by the Media Development Authority of Singapore (MDA).

The characters of "Bar" and the "Twin girls" games are original and designed by NTU final year students Haoze Zhang and Mengying Ai. The "Escape," "Shooting," "Affective shooting," "Maze," and collaborative "XEE" are original and designed by NTU final year students Philip Thomas, Yihui Qiu, Lusha Feng, Nguyen Xuan Huy, and Shiyun Lim.

References

Alvarez, J., Rampnoux, O., Jessel, J.-P., & Methel, G. (2007). Serious game: Just a question of posture. *Artificial and Ambient Intelligence, AISB, 7*, 420–423.

American Electroencephalographic Society. (1991). American electroencephalographic society guidelines for standard electrode position nomenclature. *Journal of Clinical Neurophysiology, 8*(2), 200–202.

Aspiras, T. H. & Asari, V. K. (2011). Log power representation of EEG spectral bands for the recognition of emotional states of mind. In *8th International Conference on Information, Communications and Signal Processing (ICICS) 2011*, pp. 1–5.

Boyle, E., Connolly, T. M., & Hainey, T. (2011). The role of psychology in understanding the impact of computer games. *Entertainment Computing, 2*(2), 69–74.

Bradley, M. M., & Lang, P. J. (2007). *The international affective digitized sounds (2nd edition; IADS-2): Affective ratings of sounds and instruction manual*. Gainesville: University of Florida.

Chanel, G., Rebetez, C., Bétrancourt, M., & Pun, T. (2011). Emotion assessment from physiological signals for adaptation of game difficulty. *IEEE Transactions on Systems, Man, and Cybernetics Part A: Systems and Humans, 41*(6), 1052–1063.

Clarke, A. R., Barry, R. J., McCarthy, R., & Selikowitz, M. (2001). Electroencephalogram differences in two subtypes of Attention-Deficit/Hyperactivity Disorder. *Psychophysiology, 38*(2), 212–221.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers and Education, 59*(2), 661–686.

Coyle, D., Garcia, J., Satti, A. R. & McGinnity, T. M. (2011). EEG-based continuous control of a game using a 3 channel motor imagery BCI: BCI game. In *IEEE Symposium on Computational Intelligence, Cognitive Algorithms, Mind, and Brain (CCMB)*, pp. 1–7.

Egner, T., & Gruzelier, J. H. (2001). Learned self-regulation of EEG frequency components affects attention and event-related brain potentials in humans. *NeuroReport, 12*(18), 4155–4159.

Egner, T., & Gruzelier, J. H. (2003). Ecological validity of neurofeedback: Modulation of slow wave EEG enhances musical performance. *NeuroReport, 14*(9), 1221–1224.

Emotiv. http://www.emotiv.com.

Escolano, C., Aguilar, M., & Minguez, J. (2011). EEG-based upper alpha neurofeedback training improves working memory performance. *Engineering in Medicine and Biology Society, EMBC, Annual International Conference of the IEEE, 2011*, 2327–2330.

Fuchs, T., Birbaumer, N., Lutzenberger, W., Gruzelier, J. H., & Kaiser, J. (2003). Neurofeedback treatment for attention-deficit/hyperactivity disorder in children: A comparison with methylphenidate. *Applied Psychophysiology and Biofeedback, 28*(1), 1–12.

Gunes, H. & Piccardi, M. (2005). Affect recognition from face and body: Early fusion vs. late fusion. In *2005 IEEE International Conference on Systems, Man and Cybernetics*, pp. 3437–3443.

Hanslmayr, S., Sauseng, P., Doppelmayr, M., Schabus, M., & Klimesch, W. (2005). Increasing individual upper alpha power by neurofeedback improves cognitive performance in human subjects. *Applied Psychophysiology and Biofeedback, 30*(1), 1–10.

Haptek. http://www.haptek.com.

Heinrich, H., Gevensleben, H., & Strehl, U. (2007). Annotation: Neurofeedback–train your brain to train behaviour. *Journal of Child Psychology and Psychiatry, 48*(1), 3–16.

Hou, X. & Sourina, O. (2013). Emotion-enabled haptic-based serious game for post stroke rehabilitation. In *Proceedings of the 19th ACM Symposium on Virtual Reality Software and Technology, Singapore*, pp. 31–34.

Lecuyer, A., Lotte, F., Reilly, R. B., Leeb, R., Hirose, M., & Slater, M. (2008). Brain-computer interfaces, virtual reality, and videogames. *Computer, 41*(10), 66–72.

Lee, C. M., & Narayanan, S. S. (2005). Toward detecting emotions in spoken dialogs. *IEEE Transactions on Speech and Audio Processing, 13*(2), 293–303.

Lin, Y. P., Wang, C. H., Jung, T. P., Wu, T. L., Jeng, S. K., Duann, J. R., & Chen, J. H. (2010). EEG-based emotion recognition in music listening. *IEEE Transactions on Biomedical Engineering, 57*(7), 1798–1806.

Liu, Y. & Sourina, O. (2013). EEG databases for emotion recognition. In *Proceedings of 2013 International Conference on Cyberworlds, Yokohama*, pp. 302–309.

Liu, Y., Sourina, O. & Nguyen, M. K. (2010). Real-time EEG-based human emotion recognition and visualization. In *Proceedings of the 2010 International Conference on Cyberworlds*, pp. 262–269.

Lubar, J. F. (1995). Neurofeedback for the management of attention-deficit/hyperactivity disorders. In Biofeedback: A practitioner's guide (2nd edn.) (pp. 493–522). New York: Guilford Press.

Nacke, L. E., Stellmach, S., & Lindley, C. A. (2011). Electroencephalographic assessment of player experience: A pilot study in affective ludology. *Simulation and Gaming, 42*(5), 632–655.

Nie, D., Wang, X., Shi, L. & Lu, B. (2011). EEG-based emotion recognition during watching movies. In *5th International IEEE/EMBS Conference on Neural Engineering (NER)*, pp. 667–670.

Nijholt, A., Bos, D. P.-O., & Reuderink, B. (2009). Turning shortcomings into challenges: Brain–computer interfaces for games. *Entertainment Computing, 1*(2), 85–94.

Petrantonakis, P. C., & Hadjileontiadis, L. J. (2012). Adaptive emotional information retrieval from eeg signals in the time-frequency domain. *IEEE Transactions on Signal Processing, 60*(5), 2604–2616.

Pope, A. T., & Bogart, E. H. (1996). Extended attention span training system: video game neurotherapy for attention deficit disorder. *Child Study Journal, 26*(1), 39–50.

Raymond, J., Varney, C., Parkinson, L. A., & Gruzelier, J. H. (2005). The effects of alpha/theta neurofeedback on personality and mood. *Cognitive Brain Research, 23*(2–3), 287–292.

Rego, P., Moreira, P. M. & Reis, L. P. (2010). Serious games for rehabilitation: A survey and a classification towards a taxonomy. In *2010 5th Iberian Conference on Information Systems and Technologies (CISTI)*, pp. 1–6.

Shen, L., Wang, M. & Shen, R. (2009). Affective e-learning: Using" emotional" data to improve learning in pervasive learning environment. *Journal of Educational Technology and Society, 12*(2), 176–189.

Sourina, O. & Liu, Y. (2013). EEG-enabled affective applications. In *2013 Humaine Association Conference on Affective Computing and Intelligent Interaction (ACII)*, pp. 707–708.

Sourina, O. & Liu, Y. (2014). EEG-enabled affective human-computer interfaces. In *HCI International 2014* (in print).

Sourina, O., Liu, Y. & Nguyen, M. K. (2011). Emotion-enabled eeg-based interaction. In *SIGGRAPH Asia 2011 Posters, SA'11, art. no. 10 2011*.

Sourina, O., Wang, Q., Liu, Y. & Nguyen, M. K. (2012). EEG-enabled human–computer interaction and applications. In *Towards Practical Brain-Computer Interfaces. Biological and Medical Physics, Biomedical Engineering* (pp. 251–268). Berlin, Heidelberg: Springer.

Suwa, M., Sugie, N., & Fujimora, K. (1978). A preliminary note on pattern recognition of human emotional expression. *International Joint Conference on Pattern Recognition, 1978*, 408–410.

Thomas, K. P., Vinod, A. & Guan, C. (2013). Design of an online EEG based neurofeedback game for enhancing attention and memory. In *Engineering in Medicine and Biology Society (EMBC), 2013 35th Annual International Conference of the IEEE, 2013*, pp 433–436.

Tijs, T., Brokken, D. & Ijsselsteijn, W. (2008). Creating an emotionally adaptive game. In *Entertainment Computing—ICEC 2008* (Vol. 5309, pp. 122–133) Lecture Notes in Computer Science. Berlin, Heidelberg: Springer.

Tong, Y., Liao, W., & Ji, Q. (2007). Facial action unit recognition by exploiting their dynamic and semantic relationships. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 29*(10), 1683–1699.

Truong, K. P., & van Leeuwen, D. A. (2007). Automatic discrimination between laughter and speech. *Speech Communication, 49*(2), 144–158.

Tsai, T. W., Lo, H. Y. & Chen, K. S. (2012). An affective computing approach to develop the game-based adaptive learning material for the elementary students. In *Proceedings of the 2012 Joint International Conference on Human-Centered Computer Environments 2012*, pp. 8–13.

Vernon, D., Egner, T., Cooper, N., Compton, T., Neilands, C., Sheri, A., & Gruzelier, J. (2003). The effect of training distinct neurofeedback protocols on aspects of cognitive performance. *International Journal of Psychophysiology, 47*(1), 75–85.

Wang, Q., Sourina, O., & Nguyen, M. (2011). Fractal dimension based neurofeedback in serious games. *The Visual Computer, 27*(4), 299–309.

Wang, Q., Sourina, O. & Nguyen, M. K. (2010). EEG-based "serious" games design for medical applications. In *Proceedings of 2010 International Conferenc on Cyberworlds, Singapore, 2010*, pp. 270–276.

Williams, C. E., & Stevens, K. N. (1972). Emotions and speech: Some acoustical correlates. *Journal of the Acoustical Society of America, 52*(4 Pt 2), 1238–1250.

Zeng, Z., Pantic, M., Roisman, G. I., & Huang, T. S. (2009). A survey of affect recognition methods: Audio, visual, and spontaneous expressions. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 31*(1), 39–58.

Zoefel, B., Huster, R. J., & Herrmann, C. S. (2011). Neurofeedback training of the upper alpha frequency band in EEG improves cognitive performance. *NeuroImage, 54*(2), 1427–1431.