COMAC: Educational Games for Children with ADD/ADHD

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ABSTRACT
Previous research has shown that children with Attention Deficit Disorder (ADD) and Attention Deficit Hyperactivity Disorder (ADHD) have unique difficulties that can make more traditional methods of teaching less effective. In this paper, we present a novel approach for designing computer games aimed at offering a more dynamic way of teaching ADD/ADHD diagnosed children, keeping them engaged and increasing their learning outcomes. The process of applying our design principles to two open source games (Aquaria and SuperTux) and our future plans will also be described.

Author Keywords
Game design; learning; engagement; attention deficit disorder; hyperactivity.

ACM Classification Keywords
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces; I.2.1 [**Artificial Intelligence**]: Applications and Expert Systems, Games.

General Terms
Design; Human Factors.

INTRODUCTION
The term ADD/ADHD is applied to anyone that meets the Diagnostic and Statistical Manual of Mental Disorders (DSM4) test criteria [8]. Children diagnosed with ADD/ADHD have a range of problematic behaviors such as distractibility, hyperactivity, difficulty to stay focused or following orders; sometimes they present violent behavior, social isolation and defiance to teachers and parents, which can affect their learning abilities. If a child is diagnosed with ADD it does not mean that he/she has all these symptoms ([10], [11]).

Traditional methods to teach ADD/ADHD children rely heavily on written materials. Although vast amounts of written materials are available about ADD/ADHD, there are limited resources to educate children about their condition. These children may have difficulties in the learning process, as they have trouble maintaining focus, especially when they find the task at hand boring or repetitive [1]. David Nylund mentions in his book "Treating Huckleberry Finn" that the traditional ways of teaching do not work very well on ADD/ADHD diagnosed children. They need a more dynamic way of teaching which could help them maintain their focus [16]. He has also listed a set of suggestions made by ADD/ADHD diagnosed children on how they would like to be taught, including: "Offer us Choices, Having just lectures is boring, Notice when I'm doing well and Realize that I'm intelligent".

The use of computer games as common vehicles for education, as opposed to pure entertainment, has recently gained immense popularity. In this paper, we propose a novel way to engage these children with learning material and thus improve their learning outcome. We refer to our approach as *COMAC* (edu**C**ati**O**nal ga**M**es **FOR** **A**DD/ADHD **C**hildren).

Previous research [12] has shown that educational videogames, if successfully implemented, can provide users with academic success, cognitive abilities (stimulation of different abilities like creativity), motivation (motivates children by relating learning with fun), and attention and concentration. Bogost [3] examines the advantages of using games and their potential in teaching, especially less systematic ones and argues that they promote a more critical way of thinking amongst the students. The traditional games developed purely for entertainment purposes have also been shown to enhance learning, for example: "...games like Pokemon motivate children to learn reading to a far higher level than the educational resources offered to them during the same ages" [3]. There have been some studies on health-related games mainly for encouraging physical activities, stroke rehabilitation and diabetes ([2], [4], [5], [7]), but we are not aware of any game designs specifically targeted for children with ADD/ADHD.

This paper presents the initial steps towards the development of our game design. It presents the *COMAC* design principles followed by discussion of how these principles can be applied to two existing games. It then highlights our future work.

COMAC DESIGN APPROACH
According to Kirriemuir [14], there are two key themes common to the development of games for education: (1) the desire to harness the motivational power of games in order to "make learning fun"; and (2) a belief that "learning through doing" in the form of games offers a powerful learning experience. The first theme is broadly criticised in the literature. As pointed out by Rieber et al. [17], games should not be treated simply as educational "sugar coating", making the hard work of learning easier to "swallow". Instead we have to consider both the motivational and cognitive power of games.

In view of this, rather than focusing primarily on motivating children, the idea of "learning through doing" demands much greater attention. Research evidence indicates that learning can be enjoyable experiences for children especially when they have a sense of their own progression and where the learning is relevant and conducted in a meaningful context.

The real educational value of a computer game should be exemplified by its ability to create a playful learning experience for children through experimentation, progressive exploration, trial and error, imagination, role play, and simulation. Therefore, a game designed to satisfy these criteria might stand for an ideal platform for education. Based on this understanding, it is clear to see that learning in a computer game should be purposely structured through a series of exploration tasks so that children can discover essential domain knowledge in a progressive and experimental manner. This leads to our main research question: *how can we effectively embed domain knowledge in a computer game to engage children affected by ADD/ADHD for immersive learning?*

To address this research question, the nature of computer games needs to be carefully examined. The key concept that is frequently utilised to explain the level of engagement in a computer game is that of "flow", first introduced by Csikszentmihalyi [6]. Many researchers consider flow as the state of intensive involvement. It is widely believed that flow is the key to the success of an educational game. According to Malone [15], several conditions are likely to induce the flow state. Among them, a few conditions are of particular importance for designing educational games:

C1. The activities in a game should be structured so that the level of difficulty of the game can be adjusted to match children's knowledge.

C2. The activities in a game should provide concrete feedback to children so that they can tell how well they perform and perhaps what they need to do to perform better. In particular, the performance of the game should be closely related to children's current state of knowledge of the domain.

C3. The activities in a game should present a variety of challenges such that children can obtain increasingly complex information about different aspects of domain they are learning.

It can be argued based on Malone's conditions that instead of aiming for a gaming experience that superficially conceal the educational purpose behind fun activities, a careful design of the structure of the game is highly desirable. Specifically, the game structure should contribute to the flow and subsequently the creation of an active learning environment.

Among all types of games, it appears that simulation and role play games are most likely to satisfy these requirements. In fact, learning through direct experience, which is enabled by simulation and role play, has been consistently demonstrated to be more effective and enjoyable than learning through information communicated as facts.

Based on what we found in ADD/ADHD literature and our own experience in dealing with such children, we propose COMAC – a set of design principles aimed to increase the engagement of the children with game and the teaching material covered as part of playing the game, thus improving their learning outcomes. Although our implementation of the educational features was based on the chosen games described in next Section, we believe that the six design strategies explained below are generic enough to be applied to more games. It is worthwhile to mention that these strategies can be considered as natural consequences of Malone's conditions:

- Give them clear instructions (CI) from the beginning as to what they are required to do.
- Provide constant positive feedback (PF) and recognize the effort, when the player is doing a good job and is gaining new scores.
- Give them specific goals (SG), e.g. get a certain score in order to finish a specific level.
- Encourage them to think straight (TS): our aim here is to encourage the players to slow down, analyse the situation and create a strategy rather than rushing to reach the final goal. Children with ADD are usually impatient [10, 11, 13] and because of the hyperactivity they are always rushing. TS design principle focuses on improving this behavior.
- Analyse the child's strengths and weaknesses and always display relevant scores on screen (DS)
- Encourage organizational behaviors (OB): the objective here is to help the players create the habit of planning ahead. We believe this is effective, as majority of children with ADD are disorganised [13] and planning ahead helps them address this issue.

CHOSEN GAMES

To evaluate the proposed COMAC design empirically, we had to identify appropriate games, and modify them using the proposed design strategies. Guided by Malone's conditions, efforts were made to compare and select suitable games as the basis for our quest towards tackling the research question. Many open-source games were studied in respect to their educational value. Aquaria (the open source General Public License version, http://en.wikipedia.org/wiki/Aquaria_%28video_game%29) and SuperTux (http://supertux.lethargik.org/) were finally selected, as they both enjoy a good match with Malone's conditions (i.e. C1, C2, and C3) and are considered as engaging popular games for children. The domain we picked to teach is mathematics, as children with ADD/ADHD tend to struggle with the concepts.

Aquaria is a 2D sidescrolling action-adventure game heavily focused on exploration and puzzle-solving and is available on all platforms. The player controls Naija, a lone underwater dweller; although similar to a human woman, Naija also has several fish-like qualities. The player helps Naija in her journey through the ocean where she faces different creatures and complex challenges.

SuperTux is a 2D sidescrollering platformer game in a style similar to the original Super Mario series. Here the main character is Tux (Linux mascot) that wants to save Penny from Nolok's hands. It is an open source General Public License game developed in C++ language.

Unlike SuperTux, Aquaria has a non-linear gameplay, and presents players with challenges that can be completed in a number of different sequences, thus allowing greater player freedom.

APPLYING *COMAC* TO AQUARIA & SUPERTUX

COMAC design is applied to Aquaria (Figure 1) as follows. Since we aim to teach basic math concepts, we have associated a different number to each world (each level of the game), and the player has to avoid contact with fishes with a multiple of that number attached to them. At the beginning of the game, the instructions are clearly explained (following CI principle). When Naija enters a specific area, the name and number of the world would be displayed on the screen and as long as she is travelling in that world, the number and name would remain visible on the top left corner of the screen (DS). That way, the player would be able to recall what numbers (s)he has to avoid (SG). Besides, by pausing the game, a table with the multiples of the world is displayed (CI). The multiples of the world number are attached to the bad fishes and the rest to the inoffensive ones. Naija can shoot both types of fishes but just the bad ones can hurt her. Besides there is a color associated with the number so the player can recognize more easily which numbers they have to shoot. With this design, the players are not expected to spend too much time trying to figure out which numbers are multiples or not, so the amount of time spent on each level should be more or less similar to the original version, except that the players are learning a math concept in the *COMAC* version.

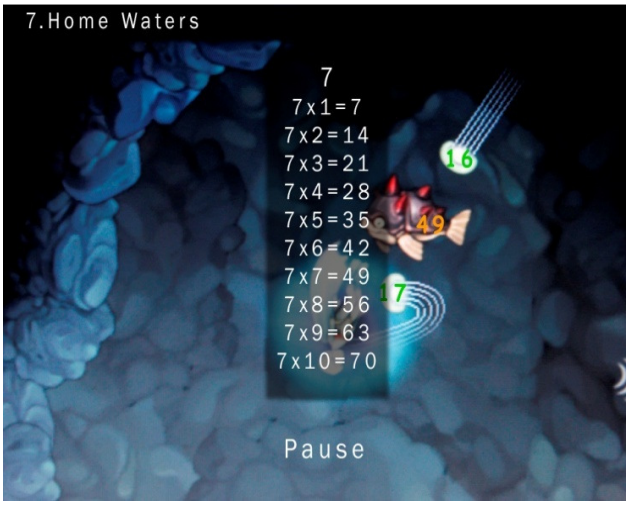

Figure 1. Example of a game level associated with multiples of seven.

Positive feedback is provided when the player has achieved something and a difficult obstacle is over come (PF). Advice is given in places where they need to observe the scenario carefully to get through the game. The advice is just to help the player to see what is important and to invite him/her to think further, without explicating telling them what to do (TS). An option of leaving marks on the map is provided for the player, so they could note things like closed pathways or places to check out later. This will help them plan things in advance and be more organised (OB). When Naija receives a lot of damage in a very short time, a warning message is displayed (TS). Aquaria is a dynamic game, in that the main character can play songs, get new abilities, interact with ocean animals, cook her own food and decorate her place. The original game has an interesting storyline to keep the children's attention. The *COMAC* version of the game is mainly designed for children who are already familiar with the math concepts (e.g. have learnt it in school) and want to practice it by playing the game. The modifications made aims to show ADD/ADHD diagnosed children that they can achieve their goal, when they are focused.

Figure 2. Tux heading towards two enemies, each of them has a number - the number used for this example is 7.

COMAC design is applied to SuperTux (Figure 2) as follows. SuperTux is an open source 2D game inspired by SuperMario. The instructions are clearly explained at the beginning of the game and the child will be able to access those anytime using the pause menu (CI). The changes would include assigning a number between 2 and 10 to each world (similar to Aquaria) depending on the difficulty of each level. The bad guys have numbers on them and Tux would have to defeat just the ones with the multiples of the number of the world it is in, in order to get to the next world (SG). The correct numbers are shown in orange and the wrong ones in green so the game play experience would be as fast as the original and the colors will help player recognize the numbers they have to hit more easily (TS). The coins would be used to gain lives and not to gain score points. The score can be increased or decreased just by defeating the bad guys. A certain score needs to be reached in each world before the player can move to the next one (SG). Each time an enemy is defeated the score goes up or down by certain number of points. This way, the player would receive immediate feedback as to how they are progressing (DS). Similar to Aquaria, the player can see the multiplication

table by just pausing the game and they are provided with positive feedback each time a world is successfully completed (PF).

However, unlike Aquaria, the player has a chance to practice more numbers with SuperTux. They have to be more selective and might find COMAC version of the game more challenging than the original one. The advantage of Aquaria is that we can add more behavior oriented changes but a disadvantage is that the main character is a mermaid – research has shown that most of the ADD diagnosed children are boys, and they might identify themselves more with a Tux than Naija.

CONCLUSIONS & FUTURE WORK

In this paper we presented the initial steps towards the development of COMAC, a novel game design for increasing engagement of ADD/ADHD diagnosed children with the domain knowledge (basic math concepts in this case), and improving their learning outcomes. We applied the design to two popular open source 2D games: Aquaria and SperTux.

We are currently establishing the experimental setting to evaluate the proposed design with primary school children diagnosed with ADD/ADHD. Three acceptance indicators will be measured: the amount of learning that takes place while playing, engagement with the game and the player's enjoyment. These will be measured while playing the original and COMAC versions of the games. We hypothesise that the COMAC games will increase their enjoyment as well as improve their learning outcomes.

Considering Gardner's seven types of intelligence [9], making COMAC games personalised to the players' skills will be our next step. We aim to present players with different challenges, e.g. linguistic, mathematical, spatial, kinesthetic, musical, interpersonal and intrapersonal, to find out which type(s) of intelligence they belong to and what their preferred way of learning is. The information gathered in this phase of the project should also help parents and educators develop children in areas they are good at. We also plan to conduct a longitudinal user study for a period of 3—6 months to examine whether using COMAC games can lead to long-term behavioural changes in children with ADD/ADHD. We believe our research paves the way for the systematic design and development of full-fledged computer games dedicated to improve their learning outcomes.

ACKNOWLEDGMENTS

The authors would like to thank Gang Chen, Abdolhossein Sarrafzadeh, Steve Marshall and Ann Faherty for their contributions in earlier stages of this project.

REFERENCES

1. ADD/ADHD in Children: Signs and Symptoms of Attention Deficit Disorder in Kids, http://helpguide.org/mental/adhd_add_signs_symptoms.htm, accesed in April 2012 (2012).
2. Alankus, G., Lazar, A., May, M. and Kelleher, C. Towards Customizable Games for Stroke Rehabilitation. In *Proc. CHI 2010*, ACM Press.
3. Bogost, I. Videogames and the Future of Education. Cambridge, Mass: The MIT, USA (2007).
4. Chen, G., Baghaei, N., Sarrafzadeh, H., Manford, C., Marshall, S., and Court, G. Designing Games to Educate Diabetic Children. In *Proc. ACM Conference of the Australian CHI Special Interest Group (OZCHI)*, Canberra, Australia, (2011).
5. Consolvo, S., Everitt, K., Smith, I., and Landay, J. A. Design Requirements for Technologies that Encourage Physical Activity. In *Proc. CHI 2006*, ACM Press (2006).
6. Csikszentmihalyi, M. Flow: The Psychology of Optimal Experience. New York: Harper & Row (1990).
7. Fujiki, Y., Kazakos, K., Puri, C., Buddharaju, P., Pavlidis, I., and Levine, J. NEAT-o-Games: Blending Physical Activity and Fun in the Daily Routine. *ACM Computers in Entertainment* 6, 2(2008).
8. Gallagher, T. Born To Explore. http://borntoexplore.org/index.html, accessed in April 2012 (2012).
9. Gardner, H. Frames of Mind: The Theory of Multiple Intelligences. New York: Basic Books (1993).
10. Gilbert, P. Helping Children Cope with Attention Deficit Disorder. Great Britain: Sheldon Press (1998).
11. Goldstein, S., and Goldstein, M. Managing Attention Deficit Hyperactivity Disorder in Children. United States of America: John Wiley & Sons, Inc (1998).
12. González, J. L., Guitiérrez, F. L., and Cabrera, M. Diseño de videojuegos colaborativos a la Educación Especial. Universidad de Granada (2007).
13. Hallowell, E. M. and Ratey, J. J. Attention Deficit Disorder. Great Britain: Fourth Estate Limited (1996).
14. Kirriemuir, J. A Survey of the Use of Computer and Video Games in Classrooms. Internal report for Becta (British Educational Communications and Technology Agency) (2002).
15. Malone. T. What Makes Things Fun to Learn? A Study of Intrinsically Motivating Computer Games. Palo Alto: Xerox (1980).
16. Nylund, D. Treating Huckleberry Finn. San Francisco: Jossey-Bass (2002).
17. Rieber, L., Luke, N. and Smith, J. Project KID DESIGNER: Constructivism at Work Through Play (1998).