Functional Fun with Tangible User Interfaces

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Abstract

This paper describes how fun can be used to maximize the learning potential of smart toys using tangible interfaces. Based on the purpose of fun the three orthogonal core sources of fun, accomplishment, discovery and bonding, are presented and linked to child development. This link is illustrated with two examples of tangible electronic games.

1. Introduction

Over the years, there have been many publications on fun, motivation, and how they can be used for the purpose of learning [1]. Many of them focus on software, e.g. video games, some on motivation in a professional teaching setting. Recently tangible computer interfaces are getting an increasing amount of attention [2]. What seems to be getting less attention is how tangible interfaces influence motivation and effect learning. In this paper we present an attempt to start to address this. Note that this is in no way complete and a lot of nuances are ignored for clarity.

In the next section we start with describing the result of a thought exercise to find the minimal set of orthogonal concepts that together cover the space of aspects that make a toy or game fun. Using these we want to be able to predict whether a toy or game is enjoyable or be able to make an existing game more engaging. Secondly, we look at how the core sources of fun relate to development and how they can be applied in learning. Next, we describe some toys and games we created to study the above relations and describe some results of these studies. We end with some conclusions.

2. Mechanics of Fun

To understand how fun works it is useful to think about why fun exists in the first place. Learning is a second order survival activity in the sense that it, as opposed to, for instance, eating does not address an immediate need but a longer term one, e.g. in the future it will help you to acquire food, preferably in a more efficient way. Learning increases our ability to survive in the future. Due to the fact that it is not acutely required for survival and it comes at a cost, it involves time and effort, it is conceivable it would benefit from some stimulation. Fun may be the evolutionary mechanism to reward increasing our ability to survive, i.e. learning, and make it intrinsically motivating. For man three aspects are important for survival: *skills, knowledge* and *social cohesion*. Hence there are three targets for learning: developing skills, gaining knowledge and bonding. For an activity to be fun it needs to incorporate at least one of these targets. From the above we may infer that the most effective ways of learning are, by them selves, intrinsically motivating. We should not be looking at how to make learning fun but how to make sure we learn the right things from fun.

2.1. Core Sources of Fun

Previous work on fun, motivation and how these are related has resulted in a variety of lists of aspects that are considered relevant for fun [1]. However, if you take into account the purpose of fun, and at least in the context of playful learning, these aspects reduce to three core sources of fun: *accomplishment, discovery, bonding*. We consider these to be orthogonal core sources as you need at least one of them for a toy or game to be fun. The best toys and games combine two or all three of them. Note that each of these aspects is composed of many component parts which often are considered separately. However, these component parts are not independent.

The first source, getting a sense of accomplishment, has to do with clear goals that can be met, perceived progress towards those goals, which implies feedback, and clear influence over that progress. It is determined by the *balance between challenge and control*. Challenge requires that given the skills of the player the task to be performed is simple enough to appear achievable, offering a sense of control to the player, but at the same time difficult enough for the outcome to be uncertain. Hence, challenge is relative to the skill level of the player and the task needs to evolve with the skills of the player to preserve challenge. The challenge offered is generally seen as the most important factor in making a game enjoyable [1].

The second source, discovery, is derived from gaining knowledge. It has to do with curiosity, being able to explore and discover new things. Exploration is the means to achieve discovery and can be fun on its own. Discovery requires ambiguity but there needs to be a *balance between ambiguity and consistency*. Information becomes knowledge if we can relate items of information to each other. To be able to do this there needs to be some consistency in the rules of the game universe. Failure to provide consistency reduces fun. Events in the game may be unpredictable but not arbitrary.

The third source, bonding, has to do with recognition and affirmation, being part of a group. Cooperation or doing something together is about the need to be needed. It creates a sense of belonging, a connection. As a herd animal humans have a higher chance of survival when they are part of a well functioning group.

Related to this aspect is competition. Competition can improve engagement [1]. Ideally there is a *balance between competition and cooperation*. Games like World of Warcraft seem to suggest that the best situation is where you cooperate in competition with other groups. Another example can be found in chapter 4. Splashball requires the players to cooperate in order to be able to compete.

2.2. Enhancement Factors

Next to core sources of fun we distinguish enhancement factors. These are factors that enhance the effectiveness of the core sources of fun but on their own do not provide fun. There are at least two, possibly three main enhancement factors: fantasy, aesthetics and maybe physicality.

The first, fantasy, has to do with a theme the game may have. It offers the possibility of experimenting with extreme and rare situations in a safe environment, improving skills that you normally do not use. It can also be used for role play, to see the view point of others by pretending to be the other in the game. This is useful for bonding.

The second, aesthetics, has to do with appearance, e.g. whether the interface is pleasing to look at or nice to touch. Beauty can also be in a form of elegance of the rules.

Physicality has to do with having an interface that is physically engaging. The reason why this enhances fun may be related to relevance, multimodality or simply that the added complexity enriches the challenge.

3. Development

The question is how can we use the above to maximize learning. As noted above, fun in play always involves some kind of learning. The trick is to ensure that what a child learns from playing is relevant, desirable.

To determine how we can use the core sources we first have to consider how a child develops. Development has three components *physical skills, cognitive skills* and *social skills*. According to Piaget each child will go through four stages of cognitive development [3]. In the first stages the child is exploring the physical world and building mental models about it. The involved cognitive skills are related to the physical (perceivable) environment. In later stages the social and more abstract cognitive skills emerge. Because development starts off with perceiving the physical reality the more advanced cognitive skills are build on that frame of reference [4].

As a result, physical (sensory) exploration has a low threshold, can be spontaneous and experienced without translation or abstraction [5] and is suitable for younger children. In fact the computing interface suitable for the youngest children must be a physical one, as illustrated by StoryToy in chapter 4. A nice side effect of a physical interface is that it is easier to share with more people, i.e. it allows collaborative use.

Developing skills is the most important part of learning and equally the sense of accomplishment is the most important fun factor. For this the challenge offered needs to match the skills and abilities of the player, in the sense that achieving the goal is likely but uncertain [1]. Therefore, the optimal challenge requires a skill set beyond the known set the player is comfortable with but within his competence. In other words, it operates within the 'Zone of Proximal Development' (ZPD) of the player [3]. This first condition for an optimal learning experience can be achieved by real-time assessment of all relevant skills of a player and fine-grained adjustment of the challenge offered for each of these skills, thereby keeping the player in his ZPD and in the sweet spot to experience fun. Next to this balancing of challenge and control one needs to balance uncertainty and consistency, competition and collaboration, and maybe fantasy and reality.

The use of the enhancement factors is relatively straightforward. Use specific themes if you want to push knowledge about specific subjects. Use aesthetics to influence the attractiveness of certain aspects. Use physicality to promote relevant motor skills, sensory exploration and to lower the threshold for use.

4. Examples of tangible educational games

In this section we will present two examples of tangible electronic games that have an educational aim, and make use of the fun sources and fun enhancement factors described in previous chapters.

The first game, StoryToy, aims to develop basic motor skills in young children, as well as cognitive skills (problem solving and language skills), and it helps to gain knowledge of the world. Depending on the implementation of the game, also the development of social skills can be supported. The second game, Splashball, stimulates children to engage in active play, supporting the development of gross and fine motor skills, and social skills.

In both cases, the level of interactivity that can be provided by technology is combined with the look and feel of traditional toys. The technology used is advanced but we have made an effort to hide it as much as possible. This also helps to preserve the ease of use of the traditional toys on which the new applications are based. The goal was that children would be able to use the toys without instruction. This will help to focus on the true learning goals, instead of having to devote effort to mastering the game interface.

4.1. StoryToy

StoryToy is a storytelling environment consisting of an audio replay engine and a tactile user interface based on a sensor network. The StoryToy environment comprises multiple characters that together can tell a story. However, the scope of StoryToy is not limited to storytelling. The same technology can be used in education, and control applications [6]. Two different instances of StoryToy will be described.

4.1.2. Interactive farm. The first application that was developed has the form of a farm, but basically any other theme could have been chosen. All that is visible is a farmhouse, several stuffed farm animals and some marked locations around the farm, like a stable box, a pond and the road. There are three modes of operation*: free play, reactive play* and *story play*. The mode of operation is selected by placing the duck on specific locations around the farm. With the duck in the stable box the system is in free play mode, which basically means that the system is turned off and the child can play without any technology enhancement. The reactive play mode is selected by placing the duck in the pond. In this mode picking up an animal results in the reproduction of the sound appropriate for that animal. For example, touching the cow produces a mooing sound. If the duck is placed on the story patch in the road the farm enters 'story play' mode and a narrator reads the first line of a story. An example is a linear story in which each story line ends with referring to one of the animals. The player now needs to touch that animal. If the correct animal is touched the appropriate sound for that animal is reproduced and the story continues. If the wrong animal is chosen the system will point this out using various responses like 'that is not the sheep' or 'that is the calf'. If the user waits too long the system will reproduce a reminder like 'I am waiting' or 'please pick up the pig'. Several stories and games with differing levels of complexity have been created and tested on children of ages between two and six. More details about this test, and about the results are presented in [6].

Figure 1: Second version of StoryToy with on the left the interactive farm and tapestry and on the right the different positions of the sun corresponding to 'morning', 'daylight', 'storm' and 'twilight'.

4.1.3. Interactive tapestry. The second version of StoryToy still uses the farm but now a wall mounted tapestry depicting a landscape is used to select the mode of operation (see Figure 1). In the sky on the tapestry there are several locations marked that can be selected by placing an object in the shape of the sun on that location, where it will stick. In addition, the system is connected to a system that enables the use of light effects in the stories next to the audio responses. If the sun is placed on the left in the sky a script starts running that dims the lights in the room and mimics a rising sun by gradually changing the color of the lamp in the east corner of the room from red to white. The other lamps gradually get brighter. Meanwhile, a game starts where the children have to identify which animals belong to the sequence of noises they hear. Other settings are: 'daylight', switching the lights to full intensity and switching the farm to reactive play mode, 'storm', lowering general light levels, featuring lightning effects and thunder, starting a story based on a dialogue between the animals over what to do during the pending storm, 'twilight', gradually dimming the light until they are off. This set-up demonstrates that lighting effects can be easily incorporated and that the tangible user-interface of StoryToy can also be used as an advanced light switch (i.e., the control option that was mentioned earlier).

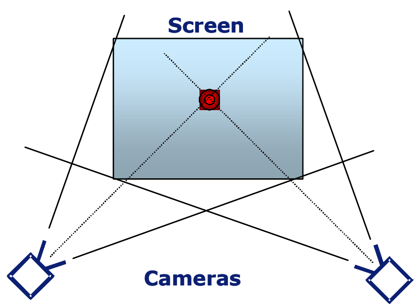

Figure 2. Impression of the camera positioning in Splasball.

4.2. Splashbal

The aim of Splashball was to create a gaming platform that was physically stimulating and, at the same time, attractive enough to lure children, but also grown-ups, away from the television and computer screens [7]. It combines image processing and camera technologies with sensor network technology.

4.2.1. Implementation. The Splashball platform uses the impact of balls on a wall as a form of point and click interface. The basic set-up of Splashball consists of a beamer and a means of impact localization. The beamer is used to project a playing field, i.e. the game, onto the wall. This is the output screen of a PC that runs the application software. To detect the impact of a ball against the wall, a motion sensor is mounted on the wall plate that receives the impact. To determine the location of the impact two cameras are mounted near the two bottom corners of the wall at a grazing angle with respect to the wall (Figure 2). The centers of the field of vision of the cameras cross near the center of the projected playing field on the wall. The cameras and motion sensor are connected to a second PC running the detection software. The detection of an impact triggers the image processing sub system to determine the location of the ball during impact by analyzing the successive frames in the image buffer at around the time of the impact trigger. This requires advanced image processing as, due to the speed of the ball, only a few frames would have the ball in them and the image of the ball exhibits substantial motion blur.

Several games have been developed that were sequential in nature to enforce that only one player throws a ball at a time – a necessary requirement given the implementation of the technologies that were used [7]. Three games were tested on adolescents. In the first game a mouse would pop up from within a giant piece of cheese. Hitting the mouse wearing a shirt of a particular color would gain a point for the player associated with that color. The object of the second game was to prevent a man from carrying a bucket of paint of a particular color across the screen by hitting it. Men that reach the other side of the screen would pour the paint into a funnel until one of the players collected a certain amount of paint. The third game featured a rabbit that was to be chased into a rabbit hole of a particular color by hitting the screen opposite from the direction the player wanted the rabbit to run, i.e. chasing the rabbit in the right direction.

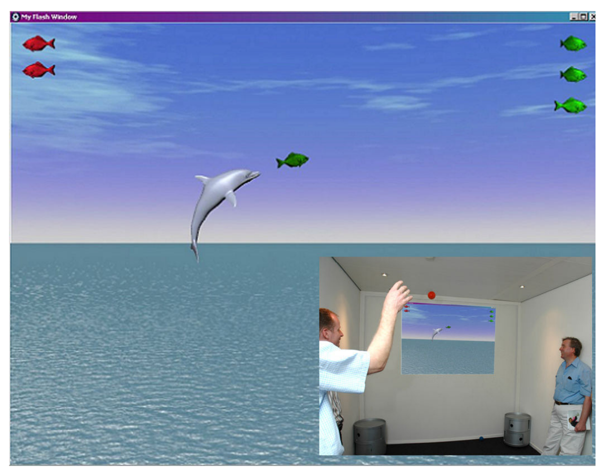

Figure 3. The large picture presents a screen shot from 'Catching fish to feed your dolphins'. The smaller picture in the lower right hand corner shows a player in the playroom throwing a ball at the screen.

Some time after these first three games were created, another game was developed. In this game, the players have to hit fish that jump out of the depicted sea (see figure 3). If a fish is hit, a dolphin will appear, and eat the fish. The player who finishes catching five fish first, wins. A more detailed description of all four games can be found in [7].

5. Discussion

We conducted tests of both toy applications, StoryToy and Splashball. Details about the design of the tests, and about the results are presented in [6,7]. Instead of discussing these results here in detail, we would like to just highlight some of the results, to support the discussion of the topics that were introduced in the first section of this paper.

5.1 StoryToy: accomplishment and discovery. With the StoryToy platform it appeared to be easy to turn simple traditional toys into environments that deliver interactive stories and games that can be quite complex and versatile, and for this reason interesting to children of different age groups. The testing of the platform with children between two to six years, demonstrated that StoryToy is fun to play with. When confronted with the stuffed animals the natural reaction of the children was to pick them up. The fact that the animals responded to this was very appealing to the children and immediately pulled them into the game. It also showed that with a 'roadmap' of complexity, the same platform can grow with the child.

StoryToy thus provides easy interaction, based on natural responses from children. Cognitive effort that does not have to be spent on understanding the interface, can now all be invested in learning other important things, e.g. about farm animals, and in developing other skills, such as language skills.

5.2 Splashball: accomplishment and bonding. Splashball was tested with adolescents between the age of 12 and 16. The vast majority of the participants in the test of Splashball rated the games as fun. What they liked about the games was throwing balls against a wall *indoors*. Also, being able to play a game without being bound to a chair and a keyboard, and being (physically) active, was seen as fun. They also liked that it was something new, and different from other games, and they liked the fact that it was designed to be played by at least two players. Playing this game with another player increased the competitive appeal, and increased the players' motivation to be active in the game.

The different games stimulated motor skill training in various ways: large and small targets to be hit, training of reaction time, precision of aiming. The fact that it is played by at least two players promotes competition but also sharing. The Splashball platform allows adapting games to the skill level of the players.

6. Conclusions

The nice thing of tangible computing is that it can easily combine all three core sources of fun (accomplishment, discovery, bonding), all three enhancement factors (fantasy, aesthetics, physicality) and address all three aspects of development (physical, cognitive, social). Thus, this type of computing is much better suited for learning then the personal computer (PC), especially for younger children. However, due to the availability of many sophisticated development tools, the creation of content for the PC is at the moment quite easy. The application of tangible computing should also become easy, to enable more people who are experts on learning to use it. Based on StoryToy and Splashball, we are developing a platform for tangible interaction that enables the fast and easy creation of toys and games that combine computing with tangible interfaces.

7. References

[1] Malone, T.W. and Lepper, M.R. "Making learning fun: a taxonomy of intrinsic motivations for learning", *Aptitude, Learning and Instruction*, Vol.3, 1987, pp.223-253; Prensky, M., "The motivation of gameplay", *On the horizon*, Vol.10, No.1, 2002; Vockell, E.L. *Educational Research* (2nd edition), Prentice-Hall, Upper Saddle River, USA, 1994.

[2] O'Malley, C. and Stanton-Fraser, D. *Literature review in learning with tangible technologies,* Nesta FutureLab Series, report 12, 2004.

[3] Sternberg, R.J., *Cognitive psychology* (2nd edition).: Harcourt Brace College Publishers, Orlando, USA, 1999.

[4] Goswami, U., "Neuroscience and education", *British Journal of Educational Psychology*, 74, 2004, pp.1-14.

[5] Ullmer, B., Ishii, H., "Emerging frameworks for tangible user interfaces", *IBM Systems Journal*, 39(3&4), 2000, pp. 915-931.

[6] Fontijn, W.F.J. and P. Mendels, "StoryToy the Interactive Storytelling Toy", *Proceedings of PerGames workshop*, Int. Conference on Pervasive Computing, Munich, Germany, 11 May 2005, pp.37-42.

[7] Hoonhout, H.C.M., W.F.J. Fontijn, and L. Smets. (2006), "Splashball: Throwing reality at the virtual world", *Proceedings of the first Fun and Games conference*, June 26-28, 2006, Preston, England.