Interactive Play Objects: The Influence of Multimodal Output on Open-Ended Play

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Abstract. In this paper we investigate how providing multiple output modalities affects open-ended play with interactive toys. We designed a play object which reacts to children's physical behavior by providing multimodal output and we compared it with a unimodal variant, focusing on the experience and creativity of the children. In open-ended play children create their own games inspired by the interaction with a play object. We show how the modalities affect the number of games played, the type and diversity of games that the children created, and the way children used the different feedback modalities as inspiration for their games. Furthermore, we discuss the consequences of our design choices on open-ended play.

Keywords: open-ended play, creativity, social interaction, interactive toys, children, multimodality, design.

1 Introduction

Children like to play: it is a vital aspect in their development and an important element in their daily lives. Open-ended play is a form of play where game rules and goals are not predetermined. Instead, the players can create their own (emerging) game goals [1], inspired by the interaction with one or multiple play objects. The goal of open-ended play is to allow children to explore and learn by creating their own game rules, by providing a simple design with many play opportunities [2]. Previous research has shown that open-ended play provides opportunities for diverse play patterns like physically active play, fantasy play, and games with rules [3]. When an object allows for creativity, children may consider it more fun and fun for a longer period of time [4]. It keeps the children focused and involved in the game. Open-ended play also offers opportunities for children to practice social behaviors – like negotiating and solving problems – while discussing about the different game rules.

We design and do research with *interactive* play objects that can be used for open-ended play. We assume that interactive toys are interesting and fun for children in exploring the possibilities of the toy (especially on the long run), because they offer many interaction possibilities to which the children can assign meaning. In [5] the authors describe how technology (sensors and actuators) in toys can stimulate children to practice both physical and social skills. In interactive open-ended play the

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players create their own games and rules based on the feedback from the interactive toys on their behavior; this stimulates the children's creativity in inventing new games. In previous studies (as described in [3]) we have shown that children are able to create different games inspired by their interaction with relatively simple interactive play objects, without predefined game rules.

The design cases discussed in previous publications [1, 2, 3] all use interactive play objects with light feedback as the only output modality. However, the question remains how the use of diverse output modalities influences the games that children come up with. We expect that multimodal feedback will have a positive impact on players' experience and inspiration, because it offers more diverse forms of output to which the players can assign meaning. Every single modality has its own specific characteristics [6]. For instance, visual feedback is always present and requires being in the field of vision; auditory feedback however is transient and the play objects do not need to be visible; haptic feedback is personal (bodily) and invisible. We expect that the qualities of the type of output will trigger particular behavior of the players and eventually affect the type of games they create. For example, objects that provide haptic feedback may trigger more secretive games than objects that emit light, because of the invisible and mysterious character of the feedback. The type of games that children play both depends on the specific characteristics of the signal (*invisibility*) and the meaning that the players assign to that signal (*mystery*). Another example: for a game based on the auditory signal the children do not necessarily need to see each other, thus facilitating a game in which the children are blindfolded, which would be impossible when light is offered as only output modality. In summary, richer output may eventually lead to more fun and more diverse games than less rich feedback, because there are more states that the players can assign meaning to.

This paper describes the design of an open-ended interactive toy which provides multimodal output. We present the set-up and results of a study in which we compared a unimodal version of the interactive play object with the multimodal variant – focusing on the experience and creativity of the children. We explored how the feedback modalities of the interactive toys affect the number of games played, the type and diversity of games that the children create, and the way children use the different forms of output in these games. On the basis of a description of children's play behavior we discuss the design considerations of such interactive toys. With this paper we take the opportunity to share the consequences of our design choices on open-ended play as inspiration for the future development of open-ended play objects.

2 Related Work

In a previous project on open-ended play a handheld interactive play object (the ColorFlare [7]) was created as a research vehicle for open-ended play and the Intelligent Playground [1]. The ColorFlare is designed to support open-ended play, and thus also social interaction and physical play. Direct manipulation of the prototype is possible by rolling it (*changing color*) and shaking it (*flashing color*). Multiple ColorFlares are able to communicate bilaterally as one ColorFlare can send its color wirelessly to another. The ColorFlares do not contain any predefined games or game rules.

Other examples of open-ended play are the Interactive Pathway [8], Flash Poles [2] and Morels [9]. The Interactive Pathway is an interactive playground installation, for young children. It consists of a pathway that can sense children's presence. When a child walks on the interactive pathway, objects that are placed alongside the pathway start spinning and in this way guide them on their walk. Flash Poles are interactive poles that are distributed on a field and can be used by children to play various physical games. Morels are mobile, cylindrical objects that can be carried around and thrown. The Morels can be 'loaded' by squeezing them and they can launch other Morels that are in the vicinity into the air. The Morels have no implemented games, only simple behavioral rules, with which players can create their own games.

Although the above-mentioned studies describe interesting concepts, these papers do not address the effect of multimodality on open-ended play. In this paper we explore the influence of multimodal feedback on open-ended play and evaluate the game experience and creativity of the children.

3 Prototype

To examine the influence of output modalities we designed the Multimodal Mixer: an open-ended play object for children in the age of 8-12. As described in [10], from eight years old onwards children start exploring the importance of rules and roles. Moreover, the children in this age group are able to create strategies and develop social skills [11]. Also, the children are independent and the group is easily within reach. These characteristics make this age group an interesting target group for open-ended play.

One of our first explorations of open-endedness for interactive play objects was done with the LEDball [1,3]. The LEDball is responsive to its environment and provides simple interactions like changing color when the object is shaken or rolled. A user study showed that children liked playing with the LEDballs and were able to create various games. It was also found that most of the games that were created were quite simple and did not explicitly use the feedback provided by the toys. As argued in the introduction, extending the interaction possibilities may lead to more diverse games and more fun. We therefore designed the Multimodal Mixer (see figure 1). The functionalities of the Multimodal Mixer are based on the LEDball (the Multimodal Mixer also requires shaking and rolling as input) and the ColorFlare (the Multimodal Mixers can also communicate wirelessly with each other) [6]. However, whereas the LEDball and the ColorFlare only provide visual feedback, the Multimodal Mixer triggers multiple senses having three different output modalities (visual, auditory and haptic feedback). We want to underline that in this paper we use the word *modality* to indicate a form of sensory output of the play object. We use the word *functionalities* to indicate the different options within a modality. For example: a unimodal play object has only one output modality (e.g. light), but may have different functionalities (e.g. rolling it changes color or shaking it causes it to start blinking).

The design of the Multimodal Mixer is simple, but it offers many play opportunities as a basis for game rules in open-ended play. No predefined game goals are linked to the design to allow children to create their own games (see figure 1).

Fig. 1. Children playing with the Multimodal Mixer during the play sessions

We deliberately used a fairly abstract shape for the Multimodal Mixer (see figure 2), because we wanted the children to make games inspired by the output modalities instead of the aesthetical features of the object. It was up to the children's imagination what could be the meaning of the object (and its output modalities) in the context of a game. Also, the interaction possibilities are uncomplicated. After all, the more specific the behavior of the objects would be to particular situations, the fewer games it can be used for.

The use of the Multimodal Mixer is independent on time and place: it is a flexible object that can be used anywhere. The Multimodal Mixer can be held in the hand (like a torch) or it can be put on the ground. In this way, the play object can be used both as a personal and as a shared play object depending on the game context, which improves the flexibility of the concept. The Multimodal Mixer responds to its environment: it

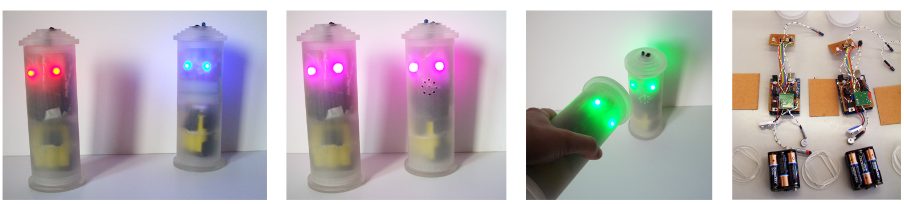

Fig. 2. The Multimodal Mixers

reacts on physical input of the players, which triggers and encourages physical play. The objects are able to communicate through an infrared signal. One child can send a signal to another child through the play objects in order to stimulate social interaction.

In order to investigate the effect of multiple output modalities on creativity and user experience, two different versions of prototypes were created: one version of interactive play objects with one single output modality (light) and another version of objects (with the same aesthetical characteristics) with multiple output modalities. The functionalities of both versions are the same. We created one prototype with two modes: a slider for the unimodal and multimodal mode to be used by the test leader only. We made four of the same prototypes to be able to test in a group setting. The functionalities are visualized in the diagram below (figure 3).

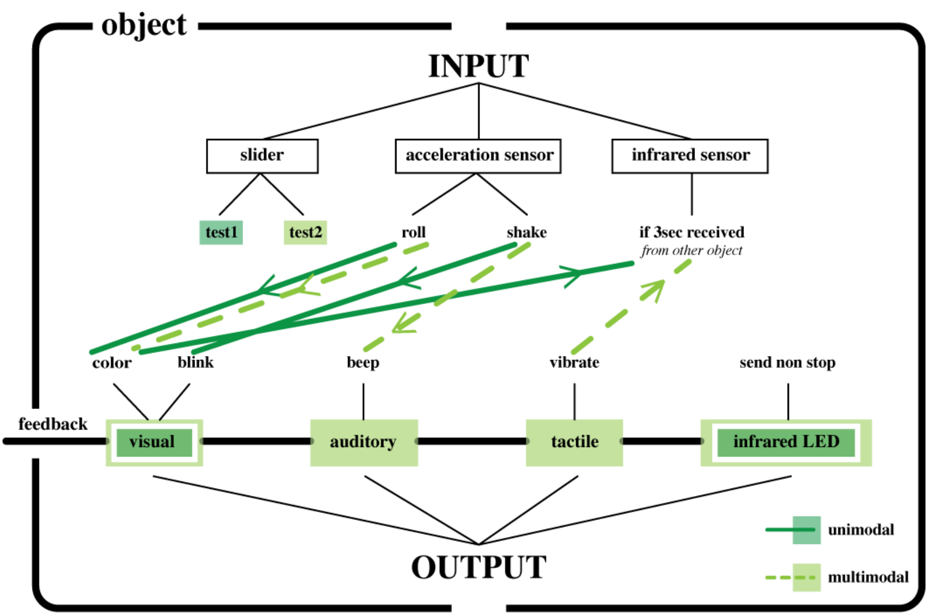

Fig. 3. Visualization of the functionalities of the Multimodal Mixer, where the straight lines indicate the interaction opportunities of the unimodal versus the multimodal version

The input side of the models contains a slider (for the mode of the object), an acceleration sensor (to detect the rolling or shaking of the object) and an infrared sensor (to detect infrared signals). The output features of the unimodal mode include full color RGB LEDs (visual) and an infrared LED (to send an infrared signal non stop). The output features of the multimodal mode include full color RGB LEDs (visual), a speaker (auditory), a vibration motor (haptic) and an infrared LED (to send an infrared signal non stop).

In the prototypes we used an Arduino Diecimilia microcontroller board for the software programming. Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software [12]. A general impression of the final prototypes is presented in figure 1.

4 Participants and Procedure

A study was carried out in which 10 groups of 3 or 4 participants (37 in total, 16 boys and 21 girls) played with the Multimodal Mixers in a free-play session. The participants of the study were children in the age of 8-12 years old.

We tested at a primary school and an after-school childcare in Eindhoven. The study was conducted with a between-subjects design. Five groups were assigned to the unimodal condition (in which they played with the unimodal play object); the other five groups were assigned to the multimodal condition (where they played with the multimodal play object).

All sessions were carried out according to the same protocol. A session started with a 5 minutes exploration phase in which the children would try and find out what they could do with the prototypes. After that, the test leader explained and demonstrated the interaction possibilities to ensure that all children started with the same understanding of the prototype. Subsequently, the children were asked to play with the prototypes for 30 minutes. The only instruction they got at this moment was to create a game. We wanted to keep the assignments in the experiment as open as possible, since we did not want to influence their play behavior. At the end of the test the children filled in a questionnaire. Every single test took approximately fifty minutes.

During the play sessions we made video recordings, which were the basis for our analysis. We counted the number of games played by each group, observed the type of games that the children created, and which functionalities they used as basis of the games they created. The categories that we used to analyze the children's play behavior were determined empirically on the basis of observations in other studies on open-ended play [7]. We defined the categories by analyzing the general descriptions of the games and the game rules: 1) *Assignment* – the children create small assignments that one person can win, e.g. roll the play object and if the object turns blue, the player wins the game; 2) *Tag* – a type of play where the children tag each other, for example by sending a signal to the other objects (inspired by games like *Catch Me If You Can*); 3) *Hide and Seek* – where either the children or the play objects are hidden in the environment and have to be found; 4) *Rolling* – in this type of play there is a central role for the interactive play objects that are rolled from one player to another; 5) *Role-playing* – the children pretend to be someone else in an act; 6) *Guessing* – a type of play where the players guess for example which object will turn yellow first; and 7) *Other* – those games that do not fit in the above-mentioned categories.

After the user experiment the participants filled in a questionnaire which was based on the Kids Game Experience Questionnaire (KGEQ) [13]. Our questionnaire addresses aspects of competence, flow and challenge, which were adopted from the KGEQ. In addition we created questions addressing creativity, social and physical aspects. Because this questionnaire has not been formally validated yet, we will not discuss the results of the questionnaire in detail in this paper. Instead, we will analyze the children's experience based on our own observations, supported by data from the questionnaire in terms of individual questions.

5 Results

First we portray how children used the objects in relation to some of our design decisions. Secondly, we describe the analysis of the data (the number and the type of games the children created and how the children used their creativity) – based on both our observations and the data derived from the questionnaire.

5.1 Design Considerations

The Multimodal Mixer has clear interaction possibilities: the children easily understood the working principles as they immediately start playing after the exploration of the play object. The aesthetics of the Multimodal Mixer triggered the children to shake or roll the object or to send a signal to another Multimodal Mixer. For instance: the shape of the head of the prototype triggered the children to send a signal and the circular form invited them to roll the prototype.

The size and shape of the object also allowed the Multimodal Mixer to be used both as a personal and as a shared play object during various games. For example: the objects were handheld and used as personal toys during *Tag* games, while in the *Assignment* category the prototypes were put upright. The flat bottom of the play object invited the object to be put on the floor – in contrast with the head of the Multimodal Mixer which is used for the sending of the signal: there is a clear difference between the upper and lower side of the object.

The children clearly made use of the flexibility of the object during the creation of new game elements. We conducted the test at two different locations and in both settings the players made full use of the entire space and its components – they even involved objects in the room as elements in the game. E.g. during a *Hide and Seek* game the players hide their Multimodal Mixer inside the furniture in the room. The flexibility of the prototype was not only reflected in the use of the environment, but also in the behavior of the children during the test. For some games the children ran around while for others they sat down at the floor, depending on the game goal. For example, during a *Tag* game where one player needed to catch the others, all players ran around, while the same children in another *Guessing* game sat down in a circle with one child in the middle who needed to guess whom of the players sent a signal to another player.

The Multimodal Mixer encourages the children to be physically active: the children used their motor skills in all of the games. Not only through the shaking and rolling of the play object, but also as a fundamental aspect of their games since most of the games that were created required physical activity. The children frequently were out of breath during and after the play session as indication that the level of physical activity was high throughout the test.

The Multimodal Mixer also stimulates social activity. Even though the test leader did not tell the participants to play *together*, all children played together in a group during the play sessions. There was not a single child that did not join a game, regardless of their age or personality. The fact that the different Multimodal Mixers were able to send and receive infrared signals contributed to this social interaction and stimulated the children to play together: the infrared communication played a crucial role in the encouragement of social play. By having an equal number of play objects and children in each group, all children were equally involved in the game. It was striking that when the objects were mixed during a previous game, the children wanted their *own* Multimodal Mixer back again during the next game – although all four Multimodal Mixers were exactly the same. Because of minor differences (like a small scratch on the casing) the children recognized their own object and claimed it as their personal one.

5.2 Creativity and Game Experience

The children in the multimodal setting created a few more games than the players who used the unimodal version of the interactive prototype (as visualized in table 1).

Table 1. Number of games per group for each test condition

	Unimodal	*Multimodal*
Average	6.5	7.1
Minimum	4	7
Maximum	13	11

In the unimodal condition the range of the number of games is quite broad. It is important to note that we did *not* stimulate the children to create as many games as possible. The group of children that created only 4 games had just as much fun as the group that created 13 games. More important was the fact that every group was able to come up with multiple games and that the children played nonstop for thirty minutes. The group that created 4 games simply played a game for a longer period. We observed that the number of games created also depends to a large extent on the character of the children, the composition of the group, the type and complexity of the games, etc.

In table 2 we describe which functionalities the children used as the basis of the games they created.

Table 2. Functionalities used per game for each test condition

	Number of games		
Functionality	*Unimodal*	*Multimodal*	*Total*
None	6	4	*10*
Rolling (Color)	18	15	*33*
Shaking (Flashing/Sound)	0	5	*5*
Sending (Color/Vibration)	13	14	*27*
Combi. of 2 functionalities	2[1]	2	*4*
Combi. of 3 functionalities	0	3	*3*
Total number of games	39	43	

[1] In this case both the sending and the color of the object play a distinctive role in the game goal. For example, in a game where a catcher needs to change the color of the objects of the other players by sending a signal. Once the object of another player changes to a specific color, that player needs to do an assignment depending on that color.

Table 3. Type of games per test condition

Type of game	*Unimodal*	*%*	*Multimodal*	*%*
Assignment	8	20.5	16	37.2
Tag	13	33.3	2	4.7
Hide and Seek	3	7.7	10	23.3
Rolling	4	10.3	5	11.6
Role-playing	4	10.3	4	9.3
Guessing	3	7.7	4	9.3
Other	4	10.3	2	4.7
Total	39	100	43	100

The use of color and infrared communication is used most frequent in both conditions. The flashing of the light (shaking) was never used in the unimodal setting, whereas sound (which requires the same input) was used in multiple game variations in the multimodal condition. Sometimes the children made combinations of two or three different functionalities. Occasionally the form of the interactive toy was more important than the functionality. In this case the players only used the tangible characteristics of the objects in their game, for example, they used the toy on the floor in the upright position.

An important finding is that the children in the multimodal condition used a wider range of functionalities in their games than the players in the unimodal condition (table 2). Apparently, offering various types of feedback made it easier to implement different functionalities in the game.

In the unimodal condition *Tagging* games are most popular, while in the multimodal condition games in the categories *Assignment* and *Hide and Seek* are played most often (table 3). The differences can be explained in terms of feedback modalities, for example, in the multimodal setting there are more diverse types of output modalities that can serve as inspiration for an *Assignment*. *Tagging* is much easier with a visible signal than an invisible one: it is clear for every single player who is tagged and who is not. Finally, it is more fun to play *Hide and Seek* with a sound or a vibration. For example: the vibration signal gives the *Hide and Seek* game a mysterious touch, because the children do not see the object, but indeed *feel* the presence of the object while they are searching. It is not exciting to look for the light of the object if an object or player is hidden in the environment (in the case of *Hide and Seek* the point is that players and objects are hidden).

We found that the children enjoyed playing with the Multimodal Mixer. The behavior of the players indicated that they liked creating their own games. The children showed that they had much inspiration for different games and indicated that they would create more games if they had the opportunity to play again. Our observations of the children's experience are supported by the results of the questionnaire. For example, children in both conditions were quite positive about whether they could use their fantasy while playing (Unimodal average: 4.05; sd.: 1.27, Multimodal average: 3.94; sd.: 1.21). The children also indicated that they had many ideas for new games (Unimodal average: 3.47; sd.: 1.35, Multimodal average: 3.29; sd.: 1.31) and that they would be able to create new games when they would have another opportunity to play with the Multimodal Mixer (Unimodal average: 3.89; sd.: 1.49, Multimodal average: 4.00; sd.: 0.97).

Although we observed that creating new games was not easy from the start (especially in the multimodal setting where the play object offered many different interaction possibilities), all children seemed to like the fact that they were left free: they found a challenge in creating their own games. The enthusiasm of the children was reflected in their behavior. Many of the players asked multiple times whether they could keep the play object or where they could buy it. These observations support the need for further development of interactive toys for open-ended play. However, only a longitudinal study can show whether open-ended play will remain to be so much fun on the long run and whether there are any differences between the different prototypes.

6 Conclusions and Discussion

Open-ended play is playing games without predefined game rules. The children create their own games inspired by the interaction with an (interactive) play object. Our aim was to explore the effect of multiple output modalities on the creativity and the game experience of the players during interactive open-ended play. We described a study in which we compared a unimodal and a multimodal interactive toy that is responsive to the behavior of the children and that provides feedback using different types of output. All children found open-ended play to be great fun.

6.1 Design Considerations for Multimodal Open-Ended Play

The qualitative results of our study provided valuable insights about the validity of our design decisions. We experienced that when designing interactive toys for open-ended play it is important to find a balance between offering an abstract shape and at the same time providing clear interaction possibilities. The more specific the aesthetics of the objects, the fewer games it can be used for. The abstract level of the aesthetical characteristics of the Multimodal Mixer (the shape, color and material) enabled the children to use their own imagination in determining what the function of the object was in a specific game context. The players assigned their own meaning to the design of the interactive toy. At the same time, it is important to note that the interaction possibilities should be clearly communicated through the shape of the object, for the children to know what they can do with the object. We recommend that an interactive play object should offer different interaction opportunities without being too complex.

The size and the shape allowed the Multimodal Mixer to be used both as personal and as shared play object: the design offered a flexible way of using the object in diverse types of play. We observed that the children find it important to have their own object in the game.

The Multimodal Mixer is not only responsive to physical input, but the physical activity is also essential in the games the children created. In this way open-ended play objects stimulate physical play. The Multimodal Mixer stimulated social play as well: all children who participated in the test spontaneously played together in a group setting. Supportive in this was the fact that the different Multimodal Mixers could communicate with each other.

6.2 The Influence of Output Modalities on Play Behavior

The quantitative results of our study research provide insights about how multiple modalities affect open-ended play behavior. Our study shows that multimodality in open-ended play is not too complex: children are able to assign meaning to the different types of feedback and translate the output to principles in different games they come up with. The children in the multimodal setting used all the different feedback modalities as inspiration in their games: they were able to assign meaning to all three types of output. They created different types of games by assigning meaning to the different types of output (where they occasionally even made combinations of the different functionalities).

The study shows that providing multiple output opportunities in open-ended play leads to richer games. That diversity has to do with the dispersal of the different functionalities used in the games and the type of games the children created depending on the modalities. However, this did not translate to a difference in experience between the multimodal and the unimodal condition; children were equally positive in both conditions.

It is important to mention that there is a limit to the number of interaction possibilities for interactive toys: the functionalities might get too overwhelming which may block the creativity of the children. Our study only shows that the step from traditional open-ended play to a richer type of open-ended play is understandable for children. Offering more interaction possibilities may make it easier for children to create games, but too many functionalities might be too complex and therefore daunting. It is important to find a balance in this by carefully choosing the functionalities of the object in such way it matches the intended function.

We expect that multimodal open-ended play will be more fun over a longer period of time, because it has more *diverse* interaction possibilities. For the further development of interactive toys for open-ended play future research needs to examine the effects of open-ended play on long-term use. Another interesting area of research is the development of intelligent interactive toys for open-ended play, that start with one output modality and gradually gains more interaction possibilities (for example in terms of output modalities): an intelligent object that increasingly grows along with the competence of its users.

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References

1. Sturm, J., Bekker, T., Groenendaal, B., Wesselink, R., Eggen, B.: Key Issues for the Successful Design of an Intelligent Interactive Playground. In: Proceedings of the 7th international conference on interaction design and children, Chicago, Illinois, pp. 258–265 (2008)

2. Bekker, T., Hoven, E., van den Peters, P., Klein Hemmink, B.: Stimulating Children's Physical Play through Interactive Games: Three Exploratory case studies. In: Proceedings of the 6th international conference on interaction design and children, Aalborg, Denmark, pp. 163–164 (2007)
3. Bekker, T., Sturm, J., Wesselink, R., Groenendaal, B., Eggen, B.: Interactive Play Objects and the Effects of Open-Ended Play on Social Interaction and Fun. In: Proceedings of the 2008 International Conference in Advances on Computer Entertainment Technology, Yokohama, Japan. ACM International Conference Proceeding Series, vol. 352, pp. 389–392 (2008)
4. Lin, T., Chang, K., Liu, H., Chu, H.: A Persuasive Game to Encourage Healthy Dietary Behaviors of Kindergarten Children. National Taiwan University (2004)
5. Bekker, T., Eggen, B.: Designing for Children's Physical Play. In: CHI 2008 extended abstracts on Human factors in computing systems, Florence, Italy, pp. 2871–2876 (2008)
6. Lemmelä, S.: Selecting Optimal Modalities for Multimodal Interaction in Mobile and Pervasive Environments. In: IMUx, Improved Mobile User Experience workshop of Pervasive 2008, the 6th international conference on Pervasive Computing, Sydney, Australia (2008)
7. Verbeek, J.: Graduation Project ColorFlare. University of Technology, Eindhoven (2009)
8. Seitinger, S., Sylva, E., Zuckerman, O., Popovic, M., Zuckerman, O.: A new playground experience: going digital? In: CHI 2006 extended abstracts on Human factors in computing systems, Montréal, Québec, Canada, pp. 303–308 (2006)
9. Iguchi, K., Inakage, M.: Morel: Remotely Launchable Outdoor Playthings. In: Proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology, Hollywood, California, vol. 266(35) (2006)
10. Acuff, D.S., Reiher, R.H.: What Kids Buy and why: The Psychology of Marketing to Kids. Simon & Schuster, Touchstone (1998)
11. Berk, L.E., Harris, S., Barnes-Young, L.: Development Through the Lifespan. Allyn & Bacon, Boston (2003)
12. Arduino, `http://www.arduino.cc`
13. Poels, K., IJsselsteijn, W.A., de Kort, Y.A.W.: Development of the Kids Game Experience Questionnaire: A Self Report Instrument to Assess Digital Game Experiences in Children. In: Extended abstract for Meaningful Play Conference, Michigan (2008)