Creating opportunities for play: the influence of multimodal feedback on open-ended play

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Abstract: In this paper, we investigate how providing multiple feedback modalities affects open-ended play with interactive toys. We designed a play object which reacts to children's physical behaviour by providing multimodal feedback 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.

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1 Introduction

Children like to play: it is a vital aspect in their development and an important element in their daily lives. By playing children explore the world and practice new skills (Parten, 1932; Piaget, 1962; Resnick, 2006; Vygotsky, 1977). Various researchers have categorised play, looking at different skills that children practice. For example, Piaget (1962) and Rubin et al. (1983) describe different types of play to indicate how children's capacity to think symbolically develops over time. At first children focus on non-symbolic practice games (first 2 years), then they are able to do more symbolic games (constructive play between 3 and 6 years old and make believe play between 2 and 6 years old) and finally they can handle symbolic games with rules from multiple points of view (between 7 years and older). Parten (1932) describes children's play in terms of coordinating their own perspective with that of others, developing from solitary to parallel, associative and finally to cooperative play. This categorisation indicates an increased ability of social interaction.

Young children play with construction toys, such as Lego and practice constructing objects and categorising objects according to shape and colour. They learn how to manipulate objects by playing with puzzles, and they practice social skills and practice what it is like to be an adult with role play toys, such as dolls, trains and dress-up costumes. How children play is influenced by their surroundings, in terms of the materials and objects available, the built environment and whether other play mates are present.

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 (Sturm et al., 2008), 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 (Bekker et al., 2008). Previous research has shown that open-ended play provides opportunities for diverse play patterns like physically active play, fantasy play and games with rules (Bekker et al., 2008). When an object allows for creativity, children may consider it more fun and fun for a longer period of time (Lin et al., 2006; McLoyd, 1983). It also keeps the children focused and involved in the game. Open-ended play also offers opportunities for children to practice social behaviours – 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 (especially on the long run), because they offer many interaction possibilities to which the children can assign meaning. Bekker and Eggen (2008) describe how technology (sensors and actuators) in toys can stimulate children to practice both physical and social skills. In interactive open-ended play the players create their own games and rules based on the feedback from the interactive toys on their behaviour; this stimulates the children's creativity in inventing new games. In previous studies (as described in Bekker et al. (2008)) 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. In our research, we examine how play object characteristics can influence play behaviour such as physical and social play (Bekker et al., in press). The study described in this paper focuses on the influence of output modality on the games that children create when playing with open-ended play objects.

The design cases discussed in previous publications (Bekker et al., 2007, 2008; Sturm et al., 2008) all use interactive play objects with light feedback as the only output modality. In this paper, we explore how the use of diverse feedback modalities influences the type of 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 feedback to which the players can assign meaning in their games. Different modalities will lead to different types of games, because every single modality has its own specific characteristics (Lemmelä, 2008). 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 feedback will trigger particular behaviour 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 feedback modality. In summary, richer feedback 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 examine whether children enjoy playing with open-ended play objects. We explore 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 feedback in these games. On the basis of a description of children's play behaviour, 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

The design of social and physical games has much in common with other types of research such as pervasive games and exertion or exergames. Pervasive (or location-aware or augmented reality) games bring the gaming experience from the world of computers and the internet into the real-world environment of the game player, by wireless and location-based technologies (Benford et al., 2005). Exergames focus on combining gaming with physical activity (Mueller et al., 2006). These games usually have embedded game goals and rules. In this section, we will focus on related work in the area of open-ended game solutions.

One of our first explorations of open-endedness for interactive play objects was done with the LEDball (Bekker et al., 2008; Sturm et al., 2008). The LEDball is responsive to its environment and provides simple interactions like changing colour 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. Also, it was found that most of the games that were created were quite simple and did not explicitly use the feedback provided by the toys. In a follow-up project on open-ended play a handheld interactive play object was created as a research vehicle for open-ended play and the Intelligent Playground (Bekker and Sturm, 2009). The ColourFlare was 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 colour) and shaking it (flashing colour). Multiple ColourFlares are able to communicate bilaterally as one ColourFlare can send its colour wirelessly to another. The ColourFlares do not contain any predefined games or game rules.

AU: The word 'ColorFlare' has been changed to 'ColourFlare' as per UK spelling. Please check.

Other examples of open-ended play are the Interactive Pathway (Seitinger et al., 2006), Flash Poles (Bekker et al., 2007) and Morels (Iguchi and Inakage, 2006). The Interactive Pathway is an interactive playground installation, for young children between 3 and 5 years old. 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. The design was created for children between 8 and 10 years old. 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 behavioural rules, with which players can create their own games. The Morels were evaluated in several user tests, with children of all ages (Iguchi, 2007). The tests showed that after an initial exploration phase many children (or groups of children) came up with a game that they could play with the Morels.

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. The Multimodal Mixer is an object that can be used in two different modes: a unimodal and a multimodal mode (which are described in more detail in Figure 4). As described in Acuff and Reiher (1998), 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 (Berk et al., 2003). 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.

As argued in the introduction, extending the interaction possibilities may lead to more diverse games and more fun. Therefore, we designed the Multimodal Mixer (see Figure 1).

Figure 1 Children playing with the Multimodal Mixer during the play sessions (see online version for colours)

The functionalities of the Multimodal Mixer are based on the LEDball (the Multimodal Mixer also requires shaking and rolling as input) and the ColourFlare (the Multimodal Mixers can also communicate wirelessly with each other) (Bekker and Sturm, 2009). However, whereas the LEDball and the ColourFlare only provide visual feedback, the Multimodal Mixer has three different output modalities, triggering multiple senses (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 using a modality. For example: a unimodal play object has only one output modality (e.g. light), but may have different functionalities using the same output modality (e.g. rolling it changes colour or shaking it causes it to start blinking). The two scenarios in Figure 2 illustrate the different type of games that can be played with the Multimodal Mixer.

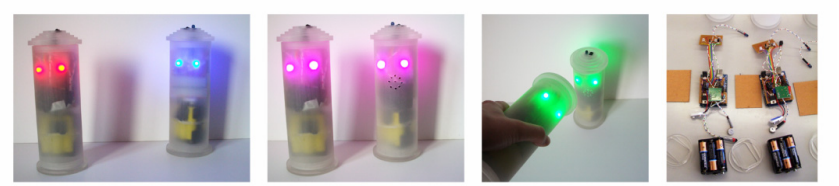
The design of the Multimodal Mixer is simple, but it offers many play opportunities as a basis for game rules in open-ended play. No predefined game goals are linked to the design to allow children to create their own games (see Figure 2).

We deliberately used a fairly abstract shape for the Multimodal Mixer (see Figure 3), 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 behaviour of the objects would be to particular situations, the fewer games it can be used for.

Figure 2 Two scenarios of how children can use the various modalities in creating games

Scenario using light output	Scenario using tactile output
Tim, Tessa and Kim are playing outside. Tessa shouts "I am going to make all your Mixers red like mine and then I win"! Kim does not want to lose, so she runs away, hiding her object behind her back. Meanwhile, Tim rolls his Mixer until it turns blue. He secretly walks behind Tessa, points his Mixers at her Mixer and makes it turn blue as well. Now both Tim and Tessa run after Kim to change the color of the Mixer. Kim tries to hide her Mixer from Tessa, which enables Tim to point his Mixer at Kim's mixer and change it to blue. Now each Mixer is blue, Tom wins!	Tim, Tessa and Kim are playing in the play room. Kim proposes to use the Multimodal Mixer to play a game of hide and seek. Tim and Tessa agree. While Tessa leaves the room, Tim and Kim hide their Mixers somewhere in the room. Then Tessa comes back. She is blindfolded and starts looking for the other two Mixers, using the vibrations of her Mixer. Aiming the Mixer in different directions she feels a vibration when another Mixer is "in sight". She finds Tim's Mixer behind the curtain. Kim's Mixer is more difficult to find, but with a little help, she finds it on top of the closet.

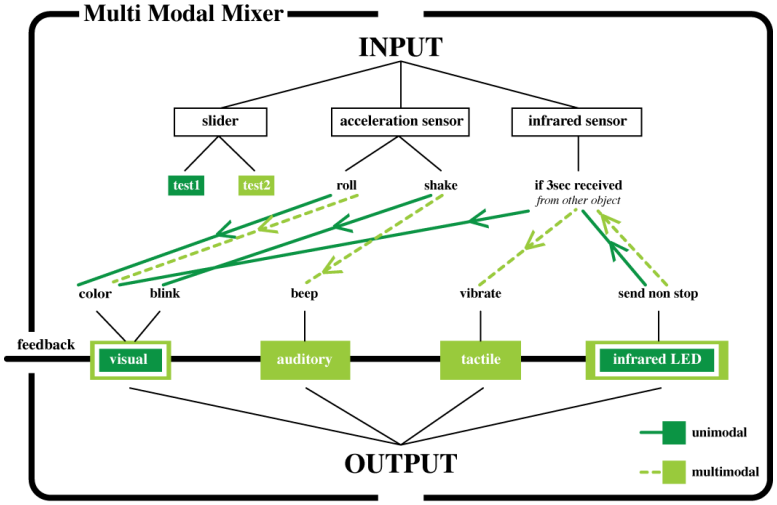
Figure 3 The Multimodal Mixers (see online version for colours)



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 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.

To investigate the effect of multiple output modalities on creativity and user experience, two interaction modes were created: one mode with one single output modality (light) and another mode (with the same aesthetical characteristics) with multiple output modalities. The functionalities of both versions are the same: shaking, rolling and sending. The mode can be selected by the test leader using a slider. We made four of the same prototypes to be able to test in a group setting. The functionalities are visualised in the diagram below (Figure 4).

Figure 4 Visualisation of the functionalities of the Multimodal Mixer, where the straight lines indicate the interaction opportunities of the unimodal vs. the multimodal version (see online version for colours)



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 colour RGB LEDs (visual) and an infrared LED (to send an infrared signal non-stop). The output features of the multimodal mode include full-colour RGB LEDs (visual), a speaker (auditory), a vibration motor (haptic) and an infrared LED (to send an infrared signal non-stop). Thus, in the unimodal mode, the object changes colour when it is rolled, it starts blinking (for 5 sec) when it is shaken, and it can always send its colour to another object. In the multimodal mode, the object changes colour when rolled (as in the unimodal mode), it sends out an auditory signal for 5 sec (with a fixed volume) when shaken and can always send a tactile signal using infrared sensors and receivers.

In the prototypes, we used an Arduino Diecimilia microcontroller board for the software programming. Arduino (2010) is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. A general impression of the final prototypes is presented in Figure 3.

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 (19 children) were assigned to the unimodal condition (in which they played with the unimodal play object); the other five groups (18 children) were assigned to the multimodal condition (where they played

with the multimodal play object). An instruction was provided at the start was decided upon as a best compromise to observe children creating games within a limited play session of 30 min. Thus, we decided to explain the functionalities after 5 min of play, to ensure that all children started with the same understanding of the prototype to ensure that all children started with the same understanding of the prototype. Allowing the children more time to find out about the interaction opportunities might have contributed to the fun of the play, but could also have made them miss opportunities for games. Furthermore, the instruction was to create a game, so that we could determine whether children were able to come up with their own games. Again, this was a compromise solution, since providing them with no task at all, might have been more natural, but might have resulted in them using too much time before creating a game, but still allowing them to create their own game goals and rules as is the intention of open-ended play objects.

All sessions were carried out according to the same protocol. A session started with a 5 min 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. Subsequently, the children were asked to play with the prototypes for 30 min. 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 behaviour. At the end of the test, the children filled in a questionnaire. Every single test took approximately 50 min.

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 analyse the children's play behaviour were determined empirically on the basis of observations in other studies on open-ended play (Verbeek, 2009).

We defined the categories by analysing the general descriptions of the games and the game rules:

1 *Assignment* – the children create small assignments that one person can win, for example, the player who is the first to roll the mixer to blue wins.

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 a scenario.

6 *Guessing* – a type of play where the players guess, for example, which object will turn yellow first.

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) (Poels et al., 2008). The KGEQ is a self-report instrument to assess game experience with children between 8 and 12 years old.

It contains 21 questions which are divided over the seven game experience modules: immersion, tension, competence, flow, negative affect, challenge and positive affect. For the purpose of our study, we wanted to ask questions related creativity, social and physical aspects. To have an acceptable amount of questions, we selected only three modules from the KGEQ: competence, flow and challenge. In addition, we created questions addressing creativity, social and physical aspects ourselves. 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 analyse the children's experience based on our own observations, supported by data from the questionnaire in terms of individual questions.

5 Results

Firstly, we describe 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. For example, during a *Hide and Seek* game the players hid 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 behaviour 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 indicating 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 recognised their own object and claimed it as their personal one.

5.2 Creativity and game experience

To examine the influence of output modality on children's ability to create games we analysed the amount of games they created, the types of games they played and how they used the functionalities in their games.

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

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. Every group was able to come up with multiple games and that the children played non-stop for 30 min. The group that created four games played the games they created for a longer period. It is difficult to tell, with the limited number of subjects in this study, whether children create a larger amount of games because they are bored with a previous game, or, for example, because they are intrigued by the diversity of opportunities of the open-ended play objects. 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 the complexity of the games.

In Table 2, we describe which functionalities the children used as the basis of the games they created. The use of colour 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.

Table 1 Number of games per group for each test condition

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

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): the children in the unimodal condition did not assign meaning to the flashing of the object, whereas in the multimodal condition they did use the sound, and they combined three functionalities in the multimodal condition.

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 (see Table 3). The differences can be explained in terms of feedback modalities (see Table 4). 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 with 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).

Table 2 Functionalities used per game for each test condition

	Number of games		
Functionality	*Unimodal*	*Multimodal*	*Total*
None	6	4	10
Rolling (Colour)	18	15	33
Shaking (flashing/sound)	0	5	5
Sending (colour/vibration)	13	14	27
Combination of two functionalities	2[a]	2	4
Combination of three functionalities	0	3	3
Total number of games	39	43	

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

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

Table 4 Overview of the relationship between the functionalities used and the games played in the multimodal condition

Type of game	*Colour*	*Vibration*	*Sound*	*2*	*3*	*None*	*Total*
Assignment	9	3	1		3		16
Tag		1		1			2
Hide and Seek	1	6	2	1			10
Rolling	2					3	5
Role-playing	2	2					4
Guessing		1	3				4
Other	1	1				1	2
Total	15	14	6	2	3	4	43

To give an impression of the kinds of games were created, we will provide some descriptions of various types of games. An *Assignment* game that used tactile output was when children had to stand in a circle and hand over the vibration Mixer. The child who is holding the object when the vibration stops loses the game. An *Assignment* game that uses colour output is when the players select a colour, and the child that is quickest in giving his/her Mixer the correct colour wins the game. They played a game of *Hide and Seek* using sound feedback. In that case, one child had to close his eyes and find the children by listening to the sound feedback of their Mixers. An example of a *Role-playing* game was that the children used the Mixers as light sabres, and were hit when their Mixer started to vibrate. They also created a light show together with all their Mixers, waving them around and watching the reflection of the colours in the windows.

During the sessions periods where children were trying to come up with new games were followed with periods where they played and they adapted the games. Overall, the children enjoyed playing with the Multimodal Mixer. We made no assumptions that children would enjoy playing more in one condition over the other, but are interested in the questionnaire scores (based on a 5-point Likert-scale) for both conditions. The competence scores of the questionnaire were fairly high for both conditions (Unimodal average: 4.19 and s.d.: 0.83, Multimodal average: 4.35 and s.d.: 0.55). The scores on flow were lower (Unimodal average: 3.91 and s.d.: 0.98, Multimodal average: 3.91 and 0.59), which is not surprising given the fact that periods of play were interwoven with periods of coming up with new games.

The behaviour 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; s.d.: 1.27, Multimodal average: 3.94; s.d.: 1.21). The children also indicated that they had many ideas for new games (Unimodal average: 3.47; s.d.: 1.35, Multimodal average: 3.29; s.d.: 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; s.d.: 1.49, Multimodal average: 4.00; s.d.: 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 behaviour. 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 behaviour 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, colour 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 study set-up on play behaviour

In the study presented in this paper, we examined the influence of the number of modalities on the play behaviour of the children. We made a number of decisions for the

set-up of the study that may have influenced the results, such as the kind of instruction that the children received at the start of the play session, the number of children and objects in a play session, and the group composition (number of boys and girls). The main difficulty of a study like this is that we examine play behaviour in a controlled setting with a limited duration, instead of examining children that decide for themselves when, with whom, how long and with what they want to play. Since we are comparing two conditions, and our main conclusions are about the differences between these conditions, it is important to keep the set-up for the two conditions as similar as possible. We intend to examine how children enjoy playing with open-ended play objects in a more natural play setting in future studies applying a more qualitative research approach.

6.3 The influence of output modalities on play behaviour

The quantitative results of our study research provide insights about how multiple modalities affect open-ended play behaviour. 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 questionnaire data indicated that they enjoy creating their own games. The data of the questionnaire should be interpreted with care, because children have been shown to choose extreme values (Read and MacFarlane, 2006). However, this is more extreme with younger children (7–9), than with older children of 12 and 13 years old.

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 (e.g. in terms of output modalities): an intelligent object that increasingly grows along with the competence of its users.

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