The Richness of Open-ended Play

Rules, feedback and adaptation mechanisms in intelligent play environments

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Abstract— **How can we design intelligent play environments for open-ended play that support richness in play? Rich play can be described as ongoing play that changes over time in character, form and nature. This paper elaborates on our initial insights on how rules and goals develop from interaction opportunities of the system, based on two pilot studies with an interactive play environment for open-ended play. Furthermore we will discuss the roles of feedback and adaptation mechanisms in the environment. Those system properties will change the interaction opportunities to match with the current situation in the play environment and to support richness in play.**

Keywords-component; Play environments; Open-ended play; Adaptation; Feedback; Rules and goals

I. Introduction

Play is of all times and omnipresent in our society [1]. Children play to discover the world around them. It serves an important function in child development to train their social and physical skills [2]. Natural play of children is often open of character. When children play, they develop their own rules and goals using artifacts at hand. A wooden stick, for example, can be used as sword in a role-play of knights, or it might be the wand of a wizard. Children's play develops in a natural and spontaneous way and in various directions and it can result in ongoing play experiences. The nature of play changes over time, as well as the rules and goals they use. Children shape their play continually. In some situation their play will be open, expressive or explorative which is referred to as ludic activities, rather than playing a game [3]. In other settings they agreed upon clear rules and goals, and their play shifts to a phase of game play [3]. Often children create a natural balance between challenge and skills, creating their own flow experience [4]. In all those play situations children self-regulate their play development. They are in control of play.

Modern technological developments increase the amount and variety of opportunities for play. Different designs support play in their own way and have their own characteristics. These developments have a profound influence on play. In contradiction to free play, for example, games on a computer are often well-defined, and they provide a never-ending stream of interaction - or rather reaction - opportunities. In general they leave less room for free interpretations. The fact that games are more structured, results in a shift of initiative of defining play from user towards technology. The users become more consumers, less creators of play. Users have less freedom in defining play.

Designs for open-ended play aim at creating a less defined setting of play [5]. In contradiction to (rule based) games, designs for open-ended play provide more possibilities and freedom for users to define play. Players have to create their own rules and goals during play, which implies negotiation between players. This fact, together with shared physical play experiences provides opportunities for social development of children [6]. Examples of traditional open-ended designs are LEGO, a sandbox or a ball. Examples of interactive designs for open-ended play are ColorFlares [5], Lusio [7] and Zoomor [8]. Those designs have in common that they only provide opportunities for interactions, and do not dictate rules or goals. Lusio [7], for example, exists of five interactive C-shaped objects that can light up in various colors. If the objects are combined, their colors are influenced in different ways, depending on the way the objects are held together. Users who play with Lusio have to explore those interactions, define meaning to them, and are free to use them in play, in any way. They can define rules for active games like interactive tag, but a role-play with 'magical color-objects' might also emerge.

What would happen if we merge elements of modern technology into an environment for open-ended play? In our research project 'intelligent play environments' (i-PE) [9] we investigate how to design such environments for open-ended play. We are researching how interactive systems for play can be designed as such; appealing elements of computer games are combined with a setting where players have more freedom to define play. We believe the open-ended character merged with modern day technology can result in an interactive environment for play with the advantage that it supports a more natural development of play. Instead of loss of control of users in classic computer games, we believe our design approach provides more control to the users. Users shape their own play, while the interactive system provides new opportunities without disturbing play. We believe this results in a play environment that supports more *richness in play*. With *richness in play* we refer to a setting where play is ongoing for a longer period and changes in character, form and nature over time. Our research project aims at gaining understanding on how to design open-ended interactive play environments, to support richness in play.

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If we would observe natural development of play it is likely we will see players change the dynamics of play; e.g. by speeding up or slowing down, changing locations of players altering play rules, or setting new goals. A system designed to support this rich form of play must be anticipating on the current situation in the play environment. We believe adaptive mechanisms and feedback are system properties that are needed to support richness. If, for example, users play more active, the system might have to speed up. On the other hand, in case of expressive play, more slow and colorful expressive effects might be more applicable. To support richness effectively, the adaptation process should somehow match the ongoing play experience; therefore some form of feedback from the occurring play to the system might be needed.

Designing the i-PE with an open-ended approach supports richness in play. Interactions are open to interpretation. Adaptive mechanisms and feedback are used to change the interactions according to the setting of play. The changes in the setting of play can result in different rules or goals in play. Interactions opportunities of the system lead to rules and goals that players use, and while the users change play over time (often including connected rules and goals) the system has to adapt the interaction opportunities. For this reason development of rules and goals is part of our research on i-PE.

This paper describes our initial insights on designing interactive play environments for open-ended play. We will focus on our insights in the development of rules and the role of adaptation and feedback. First we will shortly introduce our research project on play environments and describe our research platform GlowSteps [10]. Then we will discuss a selection of related work. Furthermore we will describe our initial insights on adaptive mechanisms, feedback and on rules in open-ended play. We will introduce our research approach and describe a first design research iteration, in which we designed two interaction behaviors for GlowSteps, each with a different focus. We evaluated both interactions with users and we will shortly describe the outcomes of the evaluations on the development of rules and goals. In both interactions we did not implement adaptive properties, yet we will discuss our thoughts on the role of adaptation and feedback for each interaction. In section 7, 'discussion' we will discuss our initial findings on the role of feedback and adaptive mechanisms and (in?) open-ended play. In the conclusion and discussion of this paper we will try to generalize our findings, and discuss future steps.

II. Introduction of Intelligent play environment project and GlowSteps

Our research project, the 'Intelligent Play Environment project' (I-PE) [9], aims at researching play environments for open-ended play. In our design approach those environments consist of multiple interactive and tangible objects. Opportunities for play arise from interactions of one or multiple of those objects. The collection of objects together with the users forms a decentralized system. A decentralized system exists of a number of separated autonomic devices that can somehow interact with each other or with the shared environment [11]. The elements have local interaction rules. Decentralized systems are known for their robust and self-organizing capabilities [11]. Those capabilities make them useful for designing play environments as they can be used in implementing adaptive mechanisms. We aim at creating a novel approach on designing objects by combining three focus areas: open-ended play approach on design for play, a decentralized system approach on system design, and a connecting factor emergence in system and play.

Figure 1. Children playing with GlowSteps

As part of our research project we developed GlowSteps [10]. GlowSteps are interactive tiles that can light up, play sound samples and sense if people stand on it. See Fig. 1. Each tile has its own microcontroller device to interpret sensor data and create output according to local interaction rules. A tile can communicate with other tiles. A set of 25 tiles forms a decentralized play environment. The collection of tiles provides opportunities for play. We designed several interaction behaviors for GlowSteps, each focusing on other aspects of the play spectrum [10].

III. Related work

Examples of designs for open-ended play are ColorFlares [5], Lusio [7] and Zoomor [8]. Those designs have in common that they only provide opportunities for interactions. Tetteroo et al. [12] describes an example of a play environment in which an open-ended approach is used to create opportunities for play. The provided opportunities change depending on the movement on the playground. The Adapting Playgrounds [13] is an example of a playground in which feedback in combination with a trained neural network is used to detect how children play. This playground exists of a set of tiles, with moving lights or 'bugs'. The speed of the bugs can be adapted. The adaptive mechanism is a good example how system properties can be changed to enrich the play experience. Nevertheless in this example the use of a trained neural-net is results in adaptive properties in interactions focused on a specific predefined selection of play behavior. Furthermore the feedback is only interpretable in this narrow scope, while natural play is much more diverse. To support this diversity, sometimes ambiguity can be helpful. An example can be found in the project 'Krul' [14]. The stick can play several sounds depending on movements it detects and on the way it is held. The sounds are ambiguous and abstract so children can use them in different contexts. ‘Krul’ has no adaptive properties, only a fixed set of sounds played depending on the movement of the stick.

The influence of differences in rules on the design of rule-based games is widely discussed. Juul [15] distinguishes games of emergence and games of progression. Progression games (e.g. the classical obstacle course based computer games, e.g. Mario Bros [16]) have to be played step-by-step. In contradiction to games of progression, in games of emergence simple rules create multiple options for the game to develop in several directions. Dormans [17] describes how to engineer for emergence in rule-based games. In his thesis he elaborates how emergence in the game system can lead to a wide variety of game dynamics from simple rules. Furthermore Dormans [17] describes how understanding feedback mechanisms in economy-based games can actually help designers to make games more interesting and more emergent. In our research project we aim at open-ended play, in which no rules or goals are provided. In this case emergence has a broader scope; next to a possible emergent character of play, the rules themselves emerge during play, often based on the provided interaction opportunities.

The MDA model [18] can be used to analyze a game with help of three lenses: mechanics, dynamics and aesthetics. The mechanics are formed by the basic components of the game, e.g. the rules of the game. Rules define what a player is ‘allowed’ or ‘obliged’ to do, and how artifacts are to be used [19]. The dynamics describe “the runtime behavior” [18] of the game. It is the actual game play. It includes how people use the system, what strategies or narratives they use, or how they influence each other during the game. This results in a user experience, which refers to the aesthetics of play in the MDA model. In the following chapter we will describe how we used the MDA model as basis for our work.

IV. Designing for open-ended interactive environments, a new challenge.

In our research project we aim at understanding how to design i-PE for open-ended play that support richness in play. This implies the i-PE design should support changes of play over time in nature, character and form. For example, in one moment players can play a fantasy play, in which they use expressive light effects of the system, while another moment, they define a game play in which they use the environment as platform for a competitive game. To support play effectively the intelligent play environment should somehow adapt its provided interaction opportunities to the changing nature, character and form of play. Therefore we believe adaptive mechanisms are needed, that use feedback of the setting of play as input.

To understand how interaction opportunities support play we need a better understanding on how users use those interaction opportunities to define rules and goals. As rules are essential qualities of a game [20] understanding how rules develop, might provide us better grip on how play evolves, how to adapt to the setting of play, and what feedback information can be used for this.

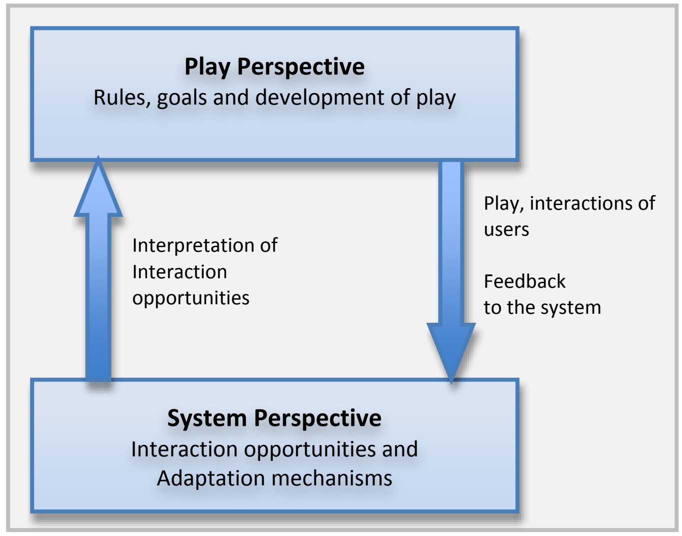


Figure 2. Perspectives on Inteligent play environments

In the following section we will propose our initial thoughts about how to approach and structure this design challenge. Furthermore we will propose a definition of different types of rules in this structure and how feedback and adaptive properties might be defined. We expect this information will help us to understand how to design play environments that provide richness in play.

A. *Perspectives of system and play*

To structure our approach we propose to think in two different views about the play environment with users. See Fig. 2. The first view is the *System perspective*. This perspective addresses system as it is. The system is the collection of interactive objects. Those objects have physical properties and have programmed interaction opportunities. They are spatially divided in a physical context. The system perspective refers to the mechanics of play in the MDA model for gaming [18]. In our open-ended setting, the mechanics do not contain the rules and goals of play, they only contain the rules for the behavior of the individual interactive objects. Users start playing with the system. Users interpret interactions, use them in play and define their own rules and goals of play. These can change continually during the development of play. This brings us to the second view: the *Play perspective*. The play perspective describes the act of playing. It describes what rules and goals, context, narrative and strategies are used in play. The play perspective is closely related to the dynamics of play of the MDA model [18].

We believe that like in rule based games; emergence and progression do play an important role in the development of play in i-PE as well. The development of play can be seen as a logical chain of events. Emergence and progression describe how those chains of events evolve and help us to understand how adaptive mechanisms and feedback can be used. In this paper the link between emergence and progression and the perspectives we use are not yet clearly defined. This will be part of future research.

B. *Adaptive mechanisms and Feedback*

To create richness in play, we believe the system will have to adapt its behavior to fit the changing setting of play. Adaptation processes imply the system can somehow sense information, and use this in a process of adaptation. Adaptation of the system implies the behavioral rules of the objects can change. This can lead to a change in nature of play. An example how interactions can influence the nature of play is the behavioral parameter proactivity. A proactive system does show initiative in changes of output, while a reactive system only reacts to user actions and does not take initiative. This will in some cases influence play; where a proactive system triggers users to act, the reactive systems might support explorative behavior. Detailed work on adaptive mechanisms including an overview on the different behavioral parameters is outside the scope of this paper.

To adapt to the current setting of play, information from the setting of play (play perspective) is needed to adapt the behavioral rules (system perspective). See Fig. 2. This information from the play perspective to the system perspective is a form of feedback. In the context of Human Computer Interaction (HCI) feedback is often used to define the information flow from the system to the user. Feedback enables the user to check whether the input he/she provided has been received, whether the system is still working [21]. This refers to Norman's interaction cycle [22]. Furthermore it plays an important role to show the user that he/ she is making progress [21].

In our proposal we aim at feedback in the other direction; from player to system. In game design this type of feedback is commonly used as a mechanism to influence the game play. Hunicke [18] describes how game designers can create a link between the dynamics of play back to the mechanics. Comparable with the classical feedback control, in games information of the game play can be used to influence the game. An example of feedback implemented in a game is Super Mario Kart [23]. A player that stays behind in the race will often receive the 'rocket bonus' that provides him or her with the chance to catch up.

In all examples of the use of feedback above the content of the feedback information is more or less defined. In rule-based games, the rules and states of the game are known, thus feedback is defined. In situations of open-ended play, we lack information: rules and goals are not a priori defined. Motives of players are unknown. One can only guess the reasons for actions in many examples. This makes the role of feedback much harder to define and underlines the challenge we face when designing for open-ended play. More restriction on play makes it easier to use feedback, but has a negative effect on the open-endedness of the interactions. More open-endedness results in more divers play, which again makes it difficult to interpret interactions.

We expect that understanding the development of rules might help us to better understand how to design adaptive mechanisms and incorporate feedback in our i-PE. Interaction opportunities in the system perspective are connected to the emerged rules in the play perspective.

C. *Rules in open-ended play*

To get better understanding of the development of rules in an open-ended play setting we propose three types of rules as basis for further analysis. We will describe those rules and connect them to the different views on system and play. First type of rules is the *Interaction opportunities* shown by the Interactive objects. This is the system behavior object in our play environment. The programmed interaction opportunities determine how the objects in the environment react to user interactions. Those rules refer to the Constitutive Rules, this are the abstract core mathematical rules as defined by Salen and Zimmerman [24] When users start playing they explore the interaction opportunities of the objects [24]. They interpret how they think the steps react. This is closely related to the interaction cycle of Norman [22]. Users create a mental model [26] of the system they are interacting with. The user's interpretation of object's interactions will be referred to as *Interpreted Rules*. Next to the interpretations users might add rules during play. (After all; this is what makes open-ended play). We will name those rules *Additional Rules*. The interpreted and additional rules are sidewise related to the Implicit Rules as defined by Salen and Zimmerman [24]. Although Salen and Zimmerman refer to Implicit Rules as the unwritten rules, they mainly aim at etiquettes, or rules of proper game behavior [24] e.g. 'one may not cheat'. Interpreted- and additional rules are unwritten rules, yet they act more as operational rules [24] that are used by players during play.

In closed games Interpreted rules are merely the agreement to follow the game- or written rules of the game, or the agreement to make changes in this set of rules. In computer games this freedom is even restricted to the game design. If users deviate from the given rules, from our point of view a closed game becomes more open-ended. The same could be said for additional rules; users can agree on adding rules to the game, in which they tend to add open-endedness. The difference between closed and open-ended play is embedded in the design values of the design. Designs for open-ended play do deliberately not dictate rules, to stimulate players to create their own. The design is always open for interpretation for users, and perhaps more important, users are free to create additional rules to enrich play.

V. DESIGN RESEARCH APPROACH

When designing objects to support open-ended play situations we encounter a specific design research challenge. In a situation of open-ended play, rules develop rather spontaneously. Interaction opportunities provided by the objects only influences the development of rules sidewise. Other factors like context of play and past experience of users influence this process as well. For this reason the development of rules cannot be predicted beforehand which makes it hard to define how to design interaction rules that support play effectively. As Hassenzahl explains in his work on UX design 'one can only design for experience not the experience themselves' [27]. For open-ended play we can make a similar statement: one cannot design how children play, only create a setting that supports the creation of their play.

Because of the fact that the relation between design choices and the actual development of play is ambiguous, an iterative approach is used to gain insights. The process we follow has several iterations of designing, evaluation and analysis and leads to rich, qualitative and situational insights [28]. One can only see if interaction opportunities are effective if tested in an actual setting of free play [29]. This exemplary qualitative approach is based on actual working designs. We aim at finding examples that help us to understand how play develops and how this is supported by the interaction opportunities. This insight can lead to new hypothesis that can be tested in a new design. Examples of a similar approach in research are [30] and [31].

In our first steps in the research work we designed interactions, and tested the interaction in play sessions with children. The interaction behaviors in the GlowSteps we used for this are simple non-adaptive interactions, designed as a first iteration. Our observations focus on how children played with the objects, interpreted the interactions and how they defined rules and goals based on their experiences. With more grip on the process of the development of rules, we expect to create new designs with adaptive properties that use feedback of information from play behavior of the users. Eventually this can lead to designs that support richness in play.

VI. EVALUATIONS OF INTERACTIONS WITH GLOWSTEPS

We designed and tested several interaction behaviors with GlowSteps. Two of those are described below. For each interaction we first describe the interaction opportunities as programmed in the GlowSteps. Then we elaborate a number of typical observations made of the play that emerged, and discuss opportunities for implementing further adaptive properties and improving feedback.

A. Design aims and expectations

We designed the two different interaction behaviors to explore the possibilities to trigger and support different types of play by using a different type of interaction rules. Table 1 presents the two interactions, with a short description of the intended design aim and a behavioral property that is changed to work towards the design aim. We have to note that the two designs are a first iteration, and the connection between design aim and behavioral property is purely a design decision, which is not based on theory.

When users explore the Catch interaction we expect them to understand (interpret) the basic idea of Catch quite easily. We added extra interaction opportunities to provide options for other behavior. (See the description of the interaction below.) The frozen state opens opportunities for users to cooperate and together catch the light more easily. This is if they interpret the interaction opportunities correctly. In Create we also create a double layer of complexity in interactions. (See the description of the interaction below.) We expect users to interpret quite easily that they can create color trails. It needs some extra effort to understand that the color can actually be influenced.

TABLE I. OVERVIEW OF TWO INTERACTION BEHAVIORS

Interaction behavior	Design aim	Behavioral property
'Catch'	The Catch behavior is intended as design to evaluate if a system with proactive properties (the moving light output) will result in active and physical play.	Proactive Design: the system proactively changes the system state, by making a light moving around
'Create'	Create is intended to trigger players to explore the interactions and to trigger creative play, in which players use the lights to create. In the Create interaction the users have to act to create.	Reactive Design: the system does not show a lot of activity without interference of the users. It merely reacts to user interactions.

B. 'Catch'

1) Description of interaction behavior

'Catch' is an interaction in which a green light attracts users by moving around from one step to a randomly selected other step. The users can catch the moving light by stepping on a step while it is lit. The steps will provide feedback (light flash in bright white) to show a user caught the light. The step that is 'caught' is fading out slowly. Some additional interactions are included to enrich the game play; if a user steps on a step that is not lit (an inactive step), the step will light up in red. This action will 'freeze' the moving green light. The moving light will now turn blue, and fades out slowly. This will provide users with more time to catch the light. If the blue light switches off or if it is 'caught', the light moves to a next step and the light will return to its normal speed, in green. The Catch behavior is intended as design to evaluate if a system with actively moving output will result in active and physical play. The interactions do not adapt in any way. If we refer to richness in play, we do not expect this interaction to support many forms of play.

2) Description of pilot study

See Table 2 for an overview of the pilot study setup.

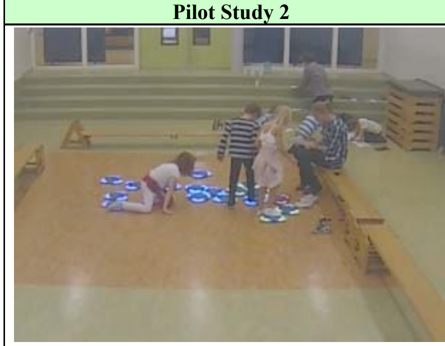
3) Summary of evaluation Catch

An example of Interaction opportunities of the GlowSteps is: If a step is not active, the step turns red if users step on it. We observed a user steps on a GlowStep. The GlowStep turns red. The user notices this. It might not be completely clear what the interaction opportunities are, but the user understands a step can become red. This is an interpretation of the interaction opportunities. We also observed users propose different rules to the fact a step can turn red. In one example a rule was mentioned that pointed out users are out of the game if they touched a red step. This is an additional rule. This rule is linked to an interpreted rule. The event of touching or catching a light creates value in play. In one observation the children started to play a Twister like game. This is an example of an additional rule, linked to

TABLE II. DESCRIPTION OF PILOT STUDY 1, ' CATCH'

Pilot Study 1	Interaction behavior: Catch	
	**Description of study:** A group of 3 children played for about 7 minutes with 10 GlowSteps. GlowSteps were placed evenly distributed on the floor. Children were told 'This is new playwear, and you may play with it. You can step on the mats and you can move them around'. The interaction was not introduced; it was up to the kids to figure out themselves while playing. One observing researcher was sitting in a corner, avoiding contact. The other researcher guided the children, and communicated with them. Researchers observed play and made notes. Sessions were videotaped.	
	Location: Gymnastics room on primary school. The room was empty.	**Description of users:** 6 groups of 3 users, between age 6 and 8 years old, randomly mixed genders.

TABLE III. DESCRIPTION OF PILOT STUDY 2, ' CREATE'

Pilot Study 2	Interaction behavior: Create	
	**Description of study**: In a group of 6 children we introduced the GlowSteps. The group was split in two, a group of 3 to 4 children played with the steps for about 15 minutes. After this session two groups switched activities. One observing researcher entertained the non-playing group. The other researcher guided the children, and communicated with them. Researchers did not avoid contact with kids, but tried to maintain a natural contact without intervention of play. Researchers observed play and made notes. Sessions were videotaped. 18 GlowSteps were used for this study	
	Location: Gymnastics room on primary school, 4 couches create playground barrier, In the back other group was making drawings.	**Description of users:** groups of 6 users, between age 6 and 8 years old, randomly mixed genders.

events. In this setting the players did not completely understand the reason of the colors changing, but it supported their play anyhow. The actions are not directly linked to the interpreted rules of the users.

The Catch interaction clearly triggered children to catch the light and to play more physically (running, challenging each other to catch the light first). The basic interaction opportunity was interpreted easily. The extra interaction, the frozen state, was often not interpreted correctly. Users did not understand the link between the change of color on one GlowStep and the fact another GlowStep was touched.

The proactive nature of Catch creates opportunities for adaptive properties in the behavior. The Catch interaction always moves after a fixed time period. In several observations we noticed children were able to catch the light better after a bit of training. This opens the opportunity for the adaptive property of speed. The steps can speed up, if they are caught more often. The Catch interaction has a clear feedback flow from play perspective to system perspective: an active step is either 'caught' by stepping on it when it is still lit or it is not 'caught'.

C. 'Create'

1) Description of interaction behavior

Magical trails of lights are a good basis to create a fantasy world around you. The Create interaction is based on this. The Create interaction shows blue twinkling light on all steps. If a user steps on a step, it will show four colors in full brightness (red, yellow, green and blue) after each other. After this cycle of colors, a randomly selected color will light up, and stay on in full brightness. If a user releases the step, the active color will slowly fade out. Finally the step starts to twinkle in blue again. If users have a good timing in jumping from step to step they will be able create a trail in one color. If users do not interact with the tiles at all, once in a while a step lights up and fades out, in a random color.

2) Description of pilot study

See Table 3 for an overview of the pilot study setup.

3) Summary of evaluation Create

In the Create interaction behavior the interaction opportunities are based on the creation of colors trails. During one of the evaluations children played hopscotch game and jumped over the path, creating a line of colors. The children used an interpreted rule 'A nice color is created when I step on a GlowStep' as bases to create. They took turns, and watched each other's results. Those are additional rules, linked to the interpreted rules. Later on a fantasy-based game emerged: the 'sleeping dragon' two children had to approach a third one that acted as a sleeping dragon. The dragon slept on a line of five GlowSteps. But as soon as the dragon was awake, the others were not allowed to move. If they did, they were out of the game. Those are examples of additional rules. The rules seem to have little relations to the interpreted rules. While the child pretends to be sleeping, he touched the five steps on which he is sleeping. This creates colors; he uses the colors as atmospheric stimuli and sometimes as trigger to wake up. The interpreted rules in this example are used sidewise to create events or stimuli that enriched the game play. The children often did not understand the color was actually partly selectable if the step was touched a precise time.

When we evaluate opportunities to implement adaptive mechanisms and feedback we see some opportunities. Adaptation could be implemented in timing of the interactions. For example the creation of a specific color could happen more easily based on past events, or based on the colors of neighbor GlowSteps. If we observe the feedback from the play perspective to system perspective, it proves to be very difficult to filter meaningful information. Why does a user make a specific color? This example shows that in some settings creating meaningful interactions cannot always be based on understanding the user's motives.

VII. DISCUSSION; A FRAMEWORK FOR DESIGNING FOR OPEN-ENDED PLAY

The relation between designed interaction opportunities from system perspective, and the development of rules, goals and more general play from the play perspective, is more complex for open-ended play than for more defined forms of play. Based on the explorations we did we came to a proposal of a theoretical framework that is suitable to deal with this complexity. We distinguish three focus areas: rules, adaptive mechanisms and feedback. These are discussed in more detail below.

A. Rules in system and open-ended play

To better understand the relation between interaction opportunities from the system perspective, and the development of rules and goals from the play perspective, we proposed the definition of different types of rules. In section 4 of this paper we described those types in more detail. Those types are: *Interaction opportunities*, *interpreted rules*, and *additional rules*.

Based on our evaluations we noticed sometimes additional rules were created that seemed to be closely connected to the actual interactions with the steps, while in other examples, this relation was less clear. This made us realize the relation between the additional rules and interpreted rules is not always the same. We propose to introduce a division based on this difference: Some additional rules seem to be connected to an interpreted rule. An example; in one of the user tests a user stated he had earned an extra point because he caught a light. In this example the user uses an interaction opportunity of the

TABLE IV. CLASSIFICATION OF RULES IN I-PE

Types of Rules	Short description
Interaction opportunities	The collection of interactions that are programmed in the play objects. Example: a GlowStep that is not lit, will light up in red if it is touched.
Interpreted Rules	An 'interpreted rule' is the interpretation of a user of an interaction opportunity. It closely related to the mental model [26] that a user creates of a system. Example: If I step on a GlowStep that is not lit, it will light up in red.
Connected Additional Rules	A connected additional rule is a rule that is added by a user, and has a close relation to an interpreted rule. Example: If I step on a GlowStep that is lit in red, I'll earn 3 credits.
Disconnected Additional Rules	A disconnected additional rule is a rule that is added by a user, and has no close relation to an interpreted rule. Example: Every GlowStep is a safe place. If I stand on them I'm safe!. (The interactions of the steps are not involved in this rule.)

system and creates additional rules that are connected to this. We will refer to this as *Connected Additional Rules*. Other examples showed rules that are less connected to the interactions with the system. An example of less connected rules is the emerging game with the 'sleeping dragon'. For example, the children have to stand still if the dragon moves. This rule is not connected to an interaction opportunity. We will refer to this as *Disconnected Additional Rules*. In Table 4 we summarized an overview of the classification of rules we recognized in a setting of open-ended play.

B. Adaptive mechanisms

How can Interaction opportunities in our Intelligent play environment support richness of play? Fixed interaction opportunities might provide several different opportunities for play. We believe adaptive mechanisms embedded in the interaction opportunities might improve the support of richness in play. Our research aims at better understanding how to implement adaptive mechanisms. In our evaluations both interactions do not have adaptive mechanisms programmed in the interaction opportunities. Nevertheless for both examples we explored options to implement adaptive mechanisms.

In the evaluations we found opportunities to implement adaptation of the system on the parameters of speed and timing. This means the actual interaction rules are not changed, but parameters in the system are. We expect this can lead to a system that can maintain challenge and flow of players in one type of game play. To create richness in play, we believe we need to extend the adaptation mechanisms to adaptation of actual interactive rules. Adaptation of rules does imply the change of the interaction opportunities. This means the environment actually has different interaction behaviors that can be activated or mixed. The different rule sets can be designed based on different behavioral parameters, like speed, timing or proactivity. For example; we could create a set of interaction rules that include 'Catch' and 'Create'. In this example we change the behavioral parameters proactivity vs. reactivity to adapt to the current setting of play.

C. Feedback

To implement adaptive mechanisms in the system, feedback of information from the play perspective to the system perspective can act as trigger in the adaptive mechanisms. Again we did not implement the use of feedback in our two interaction behaviors 'Catch' and 'Create'. In the evaluation section we only discussed opportunities to implement feedback. Nevertheless this made us aware interpretation of the information feedback in different game plays is challenging. For examples the 'Catch' interaction has an intrinsic value that creates the context of catching by showing a light that moves from step to step. This makes feedback of touching the steps of users somehow interpretable from the system perspective. The example of the 'Sleeping Dragon' shows how complex and far-fetched users can develop narratives in play as context for their play behavior. In this example it is much harder to interpret the interactions of players, and use it to adapt interactions in a meaningful way. On the other hand the example of 'Sleeping Dragon' showed a highly imaginative and rich moment of play. This made us realize the use of feedback will not always be a valid and useful approach to design adaptive mechanisms.

VIII. Conclusions & Future work

In this paper we explained our approach on designing interactive intelligent play environment for open-ended play. Our intelligent play environment is a decentralized system with multiple interactive and tangible objects. Our main challenge is to create richness in play, by implementing adaptive properties in the collection of objects. With *richness in play* we refer to a setting where play is ongoing for a longer period and changes in character, form and setting over time.

In our work we presented our approach on the design of intelligent play environments that support richness in play. We presented our insights on development of rules in open-ended play situations. Furthermore we discussed how we defined two perspectives based on the MDA model [18]: the play perspective and the system perspective. The perspectives helped us to better understand relations between interaction opportunities of the objects from the system perspective, and the occurring play development from the play perspective. Furthermore we discussed our insights on the role of adaptive mechanisms in the system, and the role of feedback to make adaptive processes connected to the development of play.

With our research environment GlowSteps we evaluated two interaction behaviors, 'Catch' and Create', in user tests. In this paper we evaluated the user sessions, summarized initial findings and analyzed them on the development of rules. Our proposed classification of rules proves to be recognizable when we analyzed our scenarios. Those rules are *Interaction opportunities*, *Interpreted rules*, *connected additional rules* and *disconnected additional rules*.

We noticed our insights on rules could be developed in more detail. This led us to the following new questions: how are the different rules related to the system perspective and play perspective? Can we pinpoint mechanisms that describe how rules and goals develop, or how rules and goals are influenced, in this context? We believe more insight in those relations might help us to better understand how to design adaptive mechanisms and feedback to enhance the support of richness in play. Those questions will be part of our future research.

Creating adaptation mechanisms that fit the richness of several settings of play is possible in different ways. Our discussion of adaptation mechanisms and feedback raises several questions for future work: How to we define behavioral properties that we change with the adaptive mechanisms? What information does this feedback flow contain? How does the system use information to make the adaptation applicable to play and what property does the system change?

In some cases this feedback will not be sufficient to create meaningful adaptive mechanisms. An example in this paper is the example of the 'sleeping dragon'. In this example children used a rich fantasy context in combination with the GlowSteps. Those cases will be of special interest in our future work.

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