About Experience and Emergence - A Framework for Decentralized Interactive Play Environments

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Abstract
Play is an unpredictable and fascinating activity. Its qualities can serve as an inspiration for design. In designing for play, we focus on play environments with players and multiple interactive objects. The current understanding of how to design these objects and interaction opportunities to create meaningful interactions and engaging user experiences is limited. In this paper a framework is introduced that focuses on decentralized interactive play environments. This framework is a challenge to create because it combines knowledge from different fields including play, user experience, emergent behavior and interactions. Two case studies demonstrate its use as a tool for analysis.

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Framework; open-ended play; emergence; user experience; interactions.

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H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces, User-centered design.

Introduction
Imagine a playground with interactive objects that can be touched, crawled into or climbed on. Children can run around and use these objects in their play. For example, they can follow a bright light that jumps from

one object to another. If they catch the light, it changes color. The children are challenged and feel competition: who catches the light first? Such a playground offers freedom to children to create their own play and provides triggers to renew play.

Play is an intrinsically motivated activity situated outside of everyday life and with no direct benefit or goal [9]. Play is unpredictable [2] and unstable [9]; it can constantly be changed or disturbed. Since long, people have been designing for play. Toys have been developed as objects to play with (e.g. buildings kits, dolls) and playgrounds as environments to play in (e.g. with swings, seesaws). Lately, these designs have become much more interactive, i.e. integrating interactive technology like sensors and actuators. Our research is part of the I-PE project which focuses on the development of interactive playgrounds that playfully persuade people to be more physically and socially active. In our view, interactive playgrounds can serve as an addition to more traditional playgrounds and they can exist next to each other.

A particular direction within designing for interactive play is open-ended play. In open-ended play, play objects offer interaction possibilities instead of ready games. Children can attach meaning to these possibilities and create their own games with them [1]. Designing for open-ended play is challenging as, in contradiction to games with rules, the emergent play behavior is hard to imagine beforehand. Environments for emergent play have the potential to lead to long-term engaging experiences. To support this emergent play, the environment has to be open, flexible and robust.

In this paper we present a framework which can serve for analyzing decentralized interactive play environments (DIPE). We define DIPE as a collection of communicating interactive elements, or agents, each with their own interaction rule set; in short, a decentralized system. These agents are able to communicate with other agents and to decide on actions based on locally available information. Decentralized systems have the ability to self-organize, to adjust to a wide variety of situations including many that were not foreseen in the design stage. Furthermore, they sometimes have emergent properties. Other benefits of decentralized systems are its scalability – the self-organizing mechanisms work even at large numbers of agents – and robustness – even when a substantial number of agents would be removed the overall system still self-organizes, still keeps going [5]. These properties fit the purpose of emergent play very well. On a higher level, DIPE and its players also form a decentralized system. The emergent play that occurs in this higher-level system is what the I-PE research project aims for.

The framework presented in this paper combines our various insights from previous work. We have looked at relations between certain design decisions and the supported playful user experiences throughout the total experience of interaction [23]. Simultaneously, the framework developed by Rozendaal et al. [18] has already shown us the bigger picture, illustrating the relations between interactive systems on one side and a design aim (behavioral change) on the other side. Yet, a more systematic overview of important elements and their relations in DIPE is needed in order to better understand the complexity of environments for emergent play. The framework presented in this paper

combines the three focus areas of play, interactions and emergence. Moreover, it supports the understanding of relationships between different elements within play environments for emergent play. The framework can help explain and understand design decisions. The framework illustrates the context of play in which the design is used, the designed (Micro) level and the emergent (Macro) level [5].

The remainder of the paper is structured as follows. First, we will give an overview of related work on play, interactions and emergence. Then we introduce our three-leveled framework. Next, we present two case studies and analyze them using the framework. This paper ends with a discussion and conclusion of the framework.

Related work

Our research connects knowledge from various fields together, including play and games, interaction design and emergence. In this section, these fields will be discussed in more detail.

Play and Games

Previous research on designing for play covers a wide gamut. One specific direction within designing for play is open-ended or emergent play; play that is not pre-defined but actually developed during use [1]. Examples of open-ended play designs are, among others, ColorFlares [1], Interactive Pathway [20] and Morel [11]. In order for open-ended play to be successful, the design should leave room for interpretation. This process can be supported by ambiguity of interaction [6, 19]. It creates an opportunity for people to establish a personal engagement with a system as they can interpret the interactions for themselves. Play is then a result of the dialogue between players and the design. This is closely related to the theory of situated action [22] which assumes that, in contrary to Norman's action cycle [14], players do not structure their activity beforehand but that the activity develops during interaction in the context of use.

Closely related to our work are two models or frameworks on play: the MDA model by Hunicke et al. [10] and the playful experiences framework by Korhonen et al. [12]. The MDA model focuses on designing for digital games and presents three components for this: Mechanics, Dynamics and Aesthetics. Mechanics concerns the components of the game, e.g. the chess pawns and board and the official rules of chess. Dynamics refers to the behavior that comes forward during play, e.g. strategies and adaptation of the rules. Aesthetics describes the experiences of the players, e.g. expressing themselves through play or wanting to win the competition. Instead of digital games, we design for environments for emergent play. In our design approach the linearity of the MDA model is less applicable, yet we do recognize the same components. By adding the design for emergence as part of the Mechanics and Dynamics, we try to enlarge the current model. We will refer to the MDA model in the description of our framework. The component of Aesthetics is related to the playful experiences framework by Korhonen et al. [12], who identified twenty playful user experiences that can support the development of playful interactive designs. In our own work, we have already built upon this work by considering the importance of time in designing interactive play objects. Three stages of play were defined as part of the overall experience of interaction

[23]. These stages are: invitation, exploration and immersion. In the invitation stage potential players are attracted towards the design. Once they start exploring the opportunities for interaction, players move to the exploration stage. The immersion stage concerns the actual play experience when players decide upon their own rules and goals.

Interaction design

In the previous section, ambiguity of interaction has been mentioned as a potential design quality for open-ended play. Ambiguity of interaction has already largely been explored in the arts. An example of this is the Senster designed by Edward Ihnatowicz (see [24]). The Senster was a robotic sculpture that reacted on sounds, but was frightened by loud sounds or if someone would try to touch it. From observing people interacting with the Senster, Ihnatowicz realized that people saw a form of animal-like intelligence in it. We believe the ambiguous nature of decentralized systems embedded in play objects might provide a similar or even richer experience for play.

Emergence

The field of emergent behavior has been widely studied in natural phenomena like the flocking behavior of birds [16] or the organizational structure of ants [7]. Resnick [15] investigated how phenomena like traffic jams can be understood by analyzing them as decentralized systems with emergent properties. Van Essen et al [3] propose a new approach in using decentralized systems in interactive designs. Fromm [4] refers to emergent properties as "a property of a system is emergent if it is not a property of any fundamental element". He describes a typical difficulty encountered when designing systems with emergent properties: emergence is the 'unexpected' macro behavior of local interaction rules of elements on micro level [5]. He proposes a design strategy combining top-down and bottom-up approaches in several iterations in order to link the micro level and the macro level of an emergent system [5]. The goal is to design the macro level, yet only the local rules of the elements can be changed.

Framework

In this section we describe our framework. The presented framework aims at providing a structured overview of focus areas that are important for developing engaging play opportunities that have the potential to lead to different types of play experiences. It illustrates the link between designed objects and emergent events. It can support designers in explaining and understanding DIPE.

Structure of the Framework

The framework is structured around three levels (see Figure 1). These levels are not mutually exclusive and can influence each other. The levels are: *Context of Play, Micro* and *Macro*. Below, all three levels will be discussed in more detail. For each level, we will give an introduction and explain their content. After that we will discuss how the different levels are related.

CONTEXT OF PLAY

This level focuses on the context of use and the overall design aim. Understanding the context of play is important as it can provide both possibilities and restrictions for (the use of) open-ended designs. Firstly, the physical environment may already determine what kind of behavior is appropriate. An outdoor playground offers more freedom to move than a small inside room.

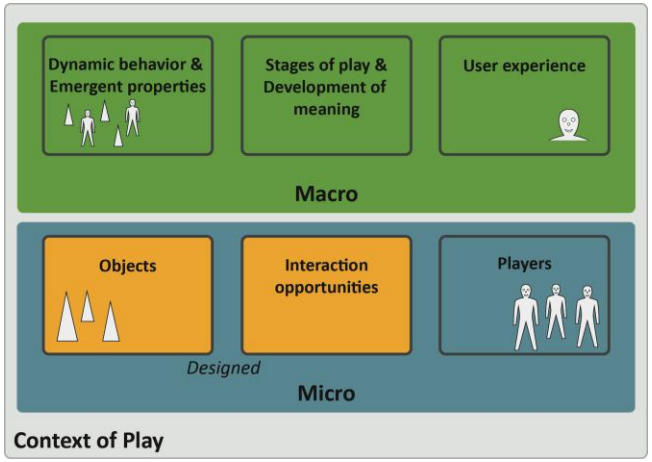

Figure 1. Framework with three levels: Context of Play, Micro and Macro.

Secondly, the social context largely influences play behavior. For example, whether people know each other influences if and how they interact with each other. Thirdly, the context is also shaped by the design aim. Defining this aim provides information to focus the concept development and to be able to validate the design. It concerns desired attitudes, behaviors and motivations of the users involved in interacting with the design. It illustrates which goal(s) the designer wanted to achieve and what the intended effect of use [13] should be.

MICRO

The Micro level describes the basic elements in a DIPE. From a design point of view, the Micro level describes the elements of the overall system that are actually designed and can be directly influenced: Objects and Interaction Opportunities. It refers to the Mechanics in the MDA model [10]. If we approach a DIPE as a decentralized system, elements in this system include both the objects and the *Player*s, as interactions between objects and players lead to dynamic behavior. *Objects* concern the designed parts of the system. Several aspects of the objects are relevant including the physical design, the interaction rules and the system states. The physical design refers to the form of the object, its size and the materials used. The interaction rules are the rules that describe how objects react on input of the players or of other objects, and what output they create. *Interaction Opportunities* are built upon the physical design and interaction rules and define the possible actions that are supported by the objects at a certain time. It should be clear to players that they can explore these opportunities [14]. For instance, the affordances of the objects (e.g. a ball triggers rolling, a button triggers pressing on it), the motivating feedback (e.g. a sound when an object is shaken) and feed forward (e.g. a tile that lights up to attract attention) that the objects provide.

MACRO

This level indicates which factors of the design emerge from interaction and can only be influenced indirectly. It includes Dynamic Behavior & Emergent Properties and Stages of Play & Development of Meaning. This refers to the Dynamics in the MDA model [10]. The Macro level also includes the User Experience, which refers to the Aesthetics in the MDA model [10].

Dynamic Behavior & Emergent Properties focuses on the decentralized system (of both objects and people) that changes over time. The collection of objects and people together create a dynamic system. The nature of the dynamic behavior needs to be considered when analyzing or designing DIPE. For example, a system

with moving lights that speeds up when players start to interact (dynamic behavior) will most likely challenge players to speed up and be physically active. *User Experience* refers to the experiences of the people interacting with the design. Experience is part of the Macro level as it emerges from the interactions of the players in the Micro level. Generally, people tend to strive for experiences that fulfill some kind of psychological need [18, 21]. Korhonen et al. provide an extensive list of examples of playful experiences [12]. *Stages of Play* [23] refers to the dynamics of play: the total experience of interaction during play that changes over time. While experiencing an interactive play environment, people move from the invitation stage to the exploration stage and to the immersion stage. In these stages, people are involved in *Development of Meaning*. They create their own rules by attaching meaning to the interaction possibilities and use these to support their current game play.

RELATIONS BETWEEN LEVELS

The different levels in the framework are closely related. The properties of the Micro level influence what happens at the Macro level. If something occurs at the Macro level (e.g. stimulation of a certain behavior or experience), this happens because of properties at the Micro level [5].

The two levels provide different perspectives on players. At the Micro level, players can be considered elements of the system during play. They form a decentralized system together with the designed objects. Players are shaped by their personal characteristics (e.g. personality, mood). At the Macro level players experience the system. We cannot directly influence those experiences, as described by Hassenzahl in his work on user experience: one cannot design the experience itself, one can only design *for* an experience, e.g. increase the likelihood for an experience to happen when interacting with the product [8]. For example, the decisions of players on how to use interaction opportunities can influence the experiences that arise from interacting with the design. This is where players form a link between Micro and Macro: there is a strong two directional relation between the actual behavior of players and the experience of players. In the same way emergence at the Macro level is supported by local interaction rules of objects at the Micro level.

As both objects and people are part of the decentralized system, this makes it a hybrid system: they both influence the overall system behavior. Thus, the emergent properties are formed and influenced by people and interactive objects. When analyzing DIPE one can distinguish three different types of communication in such a hybrid system: between objects, between players and objects and between players. These interactions form the connection between the objects and players at the Micro level and the dynamic behavior and experiences at the Macro level.

Case studies

In this section we present two case studies and describe them using the framework. The first case study is a design developed by the authors themselves. The aim of this case study is to further clarify the framework and how its components can be recognized in the design. The second case study covers a design developed by other researchers who are not familiar with the framework. In this case study, we focus on

Figure 2. Children playing with the FlowSteps.

applying the framework as an analytic tool, highlighting how the framework can be used to gain insights on potential changes or additions to the current design.

Case study 1: FlowSteps

The design FlowSteps [17, 23] is developed as part of the Intelligent Play Environments (I-PE) project (see Introduction). FlowSteps (see Figure 2) consists of multiple, interactive mats that support open-ended play. The mats provide two colors of light output that react differently on the actions of the children. When no-one is playing with the mats, one mat randomly lights up in either red or blue. If a player steps on red, the mats provide options for a next move, while stepping on a blue mat lets players choose their own next move. Players can attach meaning to the interaction possibilities and position of the mats and create rules and games together. A prototype of FlowSteps was built, consisting of six interactive mats. This prototype was evaluated to explore how to design for playful experiences in the three stages of play. Twenty children aged 7-8 years old played in pairs with the mats in a free play session at a primary school in The Netherlands (see also: [23]).

ANALYSIS

The three levels of the framework are represented in the FlowSteps in the following way. In terms of the Context of Play level, FlowSteps has the intention to stimulate physical movement and playing together. It is designed to support open-ended play. The potential target group consists of children aged 6-8 years old. At the Micro level we recognize the designed elements of the FlowSteps which are the *objects*: the six mats, and the *interaction opportunities*: a pressure sensor as input and the two colors of light, red and blue, as output. Interaction rules programmed in the mats determine which lights are active and how the mat responds to pressure or signals of the other mats. The Macro level includes the *dynamic behavior* and *emergent properties*. For the FlowSteps, these components are not fully incorporated. The emergent behavior that arises during play mainly involves the players. The behavior of the mats without players is not considered emergent. Concerning *development of meaning*, FlowSteps leaves room for players to interpret the various interaction opportunities that are part of the Micro level and attach their own meaning to them. Furthermore, the design is developed to support the total experience of interaction through the three *stages of play*: invitation, exploration and immersion. For instance, FlowSteps incorporates an active state in the invitation stage, lighting up one mat in either red or blue to attract players to start interacting with the mats. Moreover, design decisions such as the flexibility to move the mats around support the exploration stage, while the two different colors lead to different playful *experiences* in the immersion stage. Examples of these experiences are challenge, competition and fellowship.

When looking at the relations between the levels and its elements of the framework, the open-endedness of the FlowSteps at the Micro level leads to diverse forms of game play at the Macro level. Design decisions made at the Micro level clearly influences player's behaviors and experiences at the Macro level. For instance, the scarcity of the blue light inspires some children to wait for the blue light to appear. The observations also show relations between experience and development of meaning. Different play intentions result in different meanings of the interaction opportunities. Some

children focus on physically active games mostly related to competition: trying to beat the other player. For them, the lights are merely a trigger to move as fast as possible in order to catch them. Other children enjoy slower, tactic game play with the intention to discover how the objects exactly work. They consider the lights as interesting actions that need further investigation in how they can be triggered or what kind of reaction they prefer.

Case study 2: Morel

Morel is a play object designed to "facilitate the emergence of new forms of outdoor physical play" [11]. Kenji Iguchi of Keio University in Japan developed the Morel. The Morels are cylindrical shaped objects that can sense the presence of another Morel by wireless communication. If two Morels are in range, sound feedback is given to the player. If players squeeze their own Morel, another Morel in range is 'charged'. Emission of a rising tone will provide feedback about the charge. If the charge is at maximum level, the Morel will launch itself.

ANALYSIS

First, let's take a look at how the components of the framework can be recognized in the current design. Concerning the Context of Play, Morel is designed for outdoor physical play. Its aim is to create new and enriched play experiences by providing open forms of interactions. In this way people can define their own set of rules using the Morel. The Micro level includes the *objects* themselves; round cylindrical objects approximately the size of a football. Besides that, the *interaction opportunities* are formed by the foam-like appearance of the Morel which makes it shock proof and squeezable. Also, the Morel provides sound feedback when it is in range of another Morel so that players can launch this Morel by squeezing their own Morel. In the Macro level, a collection of Morels alone does not show *dynamic behavior* or *emergent properties.* The player has to interact with the Morel to activate it. The Morels create an opening to define new communication lines between players using them, in this way creating opportunities for play. *Development of meaning* is an important factor in this. People playing with the Morel should incorporate it in their play by giving the provided interaction opportunities a meaning in play.

Secondly, by analyzing this case with the framework, we thought about several potential changes for the Morel and how this would affect the resulting play. These changes may not be relevant for the current design intention but can improve the design for other intentions. One option is to increase communication between objects in order to create a decentralized system. In the current design, the communication between objects is limited and will not lead to dynamic behavior without interaction with players. Implementing different interaction rules in the design can lead to behavior that arises from only the collection of Morels. In this way not only the players influence the dynamics of the system (and thus the dynamics of play) but also the objects themselves can influence this. For example, a larger collection of Morels can start making sounds, as if the system is excited. In this way the collection of Morels starts challenging players. Another option is incorporating adaptive behavior to support for instance the stages of play. The interaction rules of the Morels can change according to the number of players or the current game played in order to support the experience of interaction over a longer period of time.

Discussion

The discussions of the case studies made us aware of the importance of apparent and less apparent links between levels and their content. Furthermore, we explored how the framework can be used to evaluate changes in the design. The framework combines multiple elements concerning play, interactions, experience and emergence. It illustrates these elements and their relationships. In this way it differs from, for example, the framework presented by [12] which focuses merely on the playful experiences, or the MDA model by [10], which is described in a rather linear setting. When developing DIPE the two models above need to be extended. With the presented framework we made a first step in analyzing relations between different elements involved in both system and play, and in the two levels, Micro and Macro.

By analyzing the case studies, we reflected mostly on the effect of design decisions and the relations between the different levels. But the framework also supported us in gaining first insights into the design process: how does designing a DIPE occur? It became clear that there is not one way of performing such a design process. It can be approached both top-down (from an experience) and bottom-up (from objects in a system). We believe developing DIPE means all elements pass view, to come to meaningful solutions. This design process will certainly be part of our future research.

Conclusion

In this paper we have presented a framework for decentralized interactive play environments. We have demonstrated the potential of the framework as a descriptive tool for analysis. Applying the framework can lead to various types of insights, concerning the elements and their relationships. For instance, specific interaction opportunities can influence or stimulate how people interpret them. Players can 'use' the available interaction opportunities of the design in their preferred way. This can eventually lead to different forms of play. The proposed framework can serve as a tool to analyze elements and their relations. In this way it serves as a contribution to other design researchers in this field. Moreover, it may also be relevant for other designers who want to design for emergence and experience. We will continue our work on this framework in future research by applying it to more cases.

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