Using an emergent system concept in designing interactive games for autistic children

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ABSTRACT
This paper features the design process, the outcome, and preliminary tests of an interactive toy that expresses emergent behavior and can be used for behavioral training of autistic children, as well as for an engaging toy for every child. We exploit the interest of the autistic children in regular patterns and order to stimulate their motivational, explorative and social skills. As a result we have developed a toy that consists of undefined number of cubes that express emergent behavior by communicating with each other and changing their colors as a result of how they have been positioned by the players. The user tests have shown increased time of engagement of the children with the toy in comparison with their usual play routines, pronounced explorative behavior and encouraging results with improvement of turn taking interaction.

Author Keywords
Autism, interactive games, emergent behavior, social interaction.

ACM Classification Keywords
J.4 [**Computer Applications**]: Social and Behavioral Sciences – *psychology*; H5.2 [**Information Interfaces and Presentation**]: User Interfaces – *user-centered design, interaction styles*.

INTRODUCTION
Autism is a developmental disorder characterized by unusual, repetitive, or severely limited activities and interests, problems with verbal and nonverbal communication, and impaired social interaction [1]. Instead of these qualities, autistic children develop strong interest in regular patterns and order and often have higher than average skills in mathematics and spatial orientation [2]. Computer games, mechanical toys and mathematical puzzles are very engaging for those children. This raises the question whether an intelligent toy can become a medium for alleviating behavioral shortcomings of the autistic children by engaging them in favorable tasks and subtly encouraging the underdeveloped behaviors.

Recently, attempts have been made to use intelligent, mainly human-like robots for behavioral treatment of autistic children [3]. There are several motivations for that. Mechanical toys with repetitively moving parts, the feeling of being in control over the robot and the predictability of the robot behavior are appealing to an autistic child. Moreover, robots can show simplified and stylized behaviors that might encourage imitation. Engaging in imitative behavior is shown to help the child to better understand social signals [7].

This approach is very interesting and inspiring, but has some limitations. It is rather restricted to imitation, and it could be a too large step for an autistic child to decide to get engaged in imitation. Moreover, humanoid robots are quite expensive and have not reached consumer market yet; they are developed in highly specialized laboratories and cannot be used at large.

Similarly, we aim at an intelligent toy that will be appealing and pleasant and in addition can encourage underdeveloped behaviors of an autistic child. Differently, we explore the interest of the autistic children in regular patterns in order to stimulate their underdeveloped skills.

Instead of targeting imitation directly, as by the humanoid robot approach, we suggest that smaller steps in the developmental training have to be taken, like stimulating explorative behavior, awareness of other selves and turn taking. In addition, we want to have a product that is more universal in use, affordable and which still has the features of an intelligent interactive toy that will keep the child motivated to play.

We have chosen the concept of constructing patterns that configure themselves in an emergent but regular manner. We hypothesize, that the fascination of the autistic children for patterns and regularity will captivate their interest, and the emergently changing behavior might stimulate their motivation to try out new things. We have chosen cubes with a size that can easily be grasped by a child, but still big enough to prevent single child to "occupy" all the cubes. This may encourage children to join their efforts in building patterns together, or at least make the child allow

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others to add to his construction, like another child or a caregiver. Emergence has previously been used in different design contexts, for instance [10, 11].

USER OBSERVATIONS

Our target user group is autistic children in the age of 5 to 9 years old. For studying the needs of young autistic patients, most of the standard methods that include direct intervention with the user group are not plausible, since autistic children might become inhibited when interacting with strangers. Instead, we used indirect methods, like interviewing caregivers, medical doctors and parents. In addition, we conducted observation at the special school. The observation was conducted by two non-communicating observers independently, each attending to 2 children in the class, for 15 minutes per child, once during playtime, once during school time.

In addition, the general structure of the class was observed in order to find out how it influences the behavior of the individual child.

8 children aged between 6 and 9 with autistic spectrum disorder were observed. Their condition varied: Pervasive Developmental Disorder, Not Otherwise Specified (PDD-NOS), classic autism, Attention Deficit Hyperactivity Disorder (ADHD), schizophrenia or combined forms of before mentioned. We list some observations that were taken into account when making design choices.

- The children had specific day task, indicated by icons and text, making it easy for them to know what they have to do on a day, and in what order.
- A typical detail about the class is that the blinds were shut all the time, to prevent excessive stimulation by events occurring outside.
- Children preferred to spend their free time on playing computer games. They also had educational programs but children showed preference to the games rather than the programs.

From the interviews and discussions with caregivers and doctors we concluded that we have to construct very simple tasks, for most children to be able to handle them. If the children are pursued to do a novel thing, or they allow somebody to take part in their game, this will be an improvement in their behavioral repertoire.

In summary, the points relevant for our design that the children should not be over stimulated; the children tend to limit themselves to use of a single sense at a time. Structure is very important to them and simple, logical games are preferred.

CONCEPT DEVELOPMENT

Multi-agent system and social behavior

A multi-agent system is a system composed of multiple autonomous components showing the following characteristics [5]:

- each agent has incomplete capabilities to solve a problem by themselves
- there is no global system control
- data is decentralized
- computation is asynchronous

Multi-agent systems can manifest self-organization and emergence of complex behaviors even when the individual rules of all their agents are simple. One or more of these rules should constitute a relation to other agents. Multiple agents together form a system, which expresses emergent behaviour as a direct result of the interaction between agents.

This is in some way comparable to what happens when several people are brought together. They all have their own (very complex) rules-set, consisting of norms and values, feelings, goals and so forth. When they start communicating, they start influencing each other and complex social behaviour may emerge.

As autistic people tend to make things comprehendible by seeking patterns to structure it, such Multi Agent Systems are likely to appeal to them. Furthermore, having full and direct control on the state of the system should make them feel at ease [4, 8].

By trying to compose the rules in such a way that the emergent behaviour resulting from them could be perceived as social, we hope to make this society of cubes comprehendible to the children and ultimately, the real society, if only a little bit.

Initial user test.

To be able to test this hypothesis, initially a virtual prototype was created using Macromedia Flash 8. The application consists of nine blocks that have a predefined color (Figure 1a). When dragged by the mouse blocks change their position. When in contact, they change their color based on the color of neighboring blocks. In this specific experimental setting the blocks take the color of their neighbor.

Four autistic children between the ages of 4 to 6 years old have been observed using this application (a little younger than the actual target group). They all played the same game and were observed for about 15 minutes. All the children were interested by either construction of blocks or the changing colors of the blocks. Two children saw the relation between building and changing colors and even discovered some patterns in the colors. We considered that the concept is feasible, and a decision was made to progress with the physical prototype.

Translating the simulated game to a physical toy requires different design decisions. The tangible blocks have to have the same interaction abilities, better appeal and have to be more suitable for pursuing the children to explore playing together. The cubic shape was chosen for the agents to be able to form a grid in order to make spatial relations more obvious. In addition, the cubes can be stacked, enabling more complex structures. The dimensions were chosen to be 10 by 10 for the following reasons: both hands of the children have to be used, so fine motoric skills are not required, respecting the underdevelopment of the precision grip skills by many autistic children. Furthermore, the cubes are small enough to be used on a tabletop and big enough to be used on the ground.

As the blocks are to be handled by children with diverse capacities, and to avoid excessive stimulation, the interaction protocol has been kept as simple as possible. The cubes can change color using light emitting diodes, and detect the color of each other using infrared communication on all six sides. Light is used as medium for interactive expression, since it was found to be attractive means for reward for autistic persons [6]. To avoid excessive stimulation, the light diodes are covered with an external cube of white Plexiglas (PMMA), which diffuses the light emission. Figure 2a shows the cubes in a dark room, but in daylight the effect is softened considerably.

A programmable PIC microcontroller is embedded in each cube to calculate the cubes reaction to placement. This calculation is local for every cube, to conform to the multi-agent concept. Preprogrammed rules are used only to control the behavior of the individual cube, but all blocks together show group behavior. When the children move the cubes, the color of each cube–agent is changed according to its relative position to the other cubes, their color and its own color. Since the cubes cannot move on their own, the children are in control of every change in state of the system. The cubes design and operation is illustrated in Figure 2.

The cubes only detect each other within certain boundaries, as shown in Figure 2b. These boundaries are generous enough to be handled by children with motoric problems, while still allowing the cubes to form a grid. In order to facilitate handling the blocks, they were kept as light as possible. Another important feature of the cubes is that different rules-sets can be changed remotely, in order to fit the level of the children or the requirements of an experimenter. As the cubes can be reprogrammed easily as well, they form quite a dynamic platform.

USER TEST

After the working prototype was finished, the design decisions had to be justified and the hypothesis for the therapeutic potential of the toys had to be confirmed. In order to test the influence of the emergent behavior, we planned on testing two different behaviors on five children; one based on emergence and one on randomness whenever the cubes are repositioned.

First, the user test confirmed the suitability of most of the design choices. As it was expected, the colored lights and their alternations caught the children's attention. Moreover, the response of the children was pleasant.

It was observed that every child, with exception of one, kept his/her attention to the cubes for the complete two sessions of ten minutes. Three children afterwards indicated that they wanted more time to play with the toy. We interpret this result as positive, since the autistic children quickly loose the motivation to explore new objects [9].

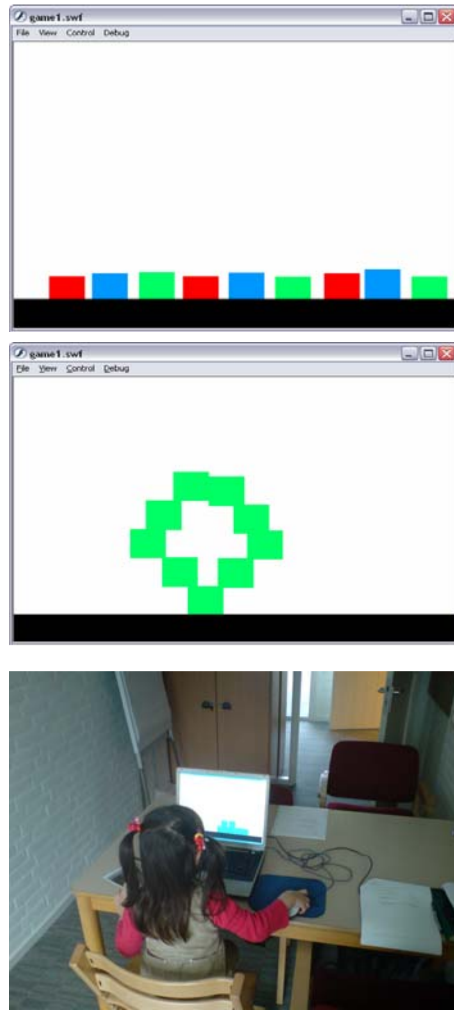

Figure 1: a) Initial setting of the blocks. b) Emergent pattern after stacking. c) Initial user test with the simulated game for verifying the design concept.

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interaction

Interaction

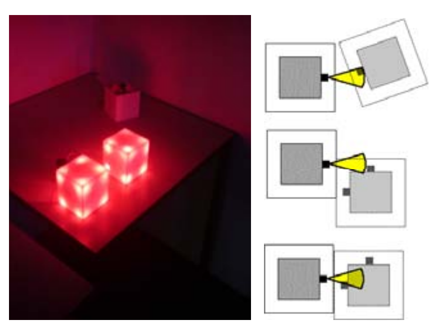

Figure 2: a) Two interacting cubes. b) Sensor placement facilitating grid formation.

Every child was able to stack and play in other ways with the blocks. At certain times the blocks were treated roughly, so improvement of the robustness and softness of the cubes should be made.

On the basis of the data gathered from the user test, a comparison was made that indicates that our product encourages explorative behavior in autistic children that may counteract repeated erroneous behavior typical for this user group [1], (Figure 3). An example of an observation supporting this is the fact that one of the children, who by chance saw that a block changed color after putting it under the heating system, started putting all the blocks there.

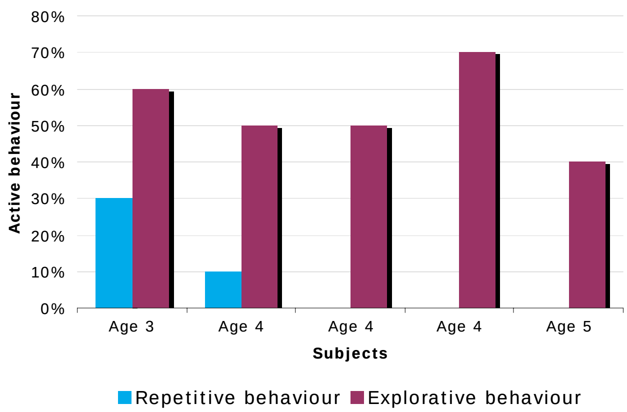

Figure 3: Repetitive and explorative behavior expressed in percentage of test-duration. The data shows pronounced explorative behavior.

DISCUSSION

From the results of the user test, we are able to conclude that most design decisions were justified, making the product easy and fun to use for this group of children. There was small failure in the functioning of the blocks during the user test, which prevented us from testing the impact of emergence on the children's motivation to play with the blocks.

Instead, we were able to confirm, both from the preliminary and the actual user test that the children did not loose motivation to play and they clearly showed explorative behavior as a result of the random changes in color alone.

We have the hope that trying to understand the functioning of multi-agent systems may make autistic children become more motivated and aware in gaining understanding of the most complex multi-agent system, the society, although an experiment confirming this hypothesis is beyond the scope of this paper.

Currently we have a prototype that can be used for stimulating the explorative and social behavior of autistic children.

The re-programmability of the cubes makes them a useful research platform for testing different hypotheses, like the influence of light, patterns, interaction etc. In addition, the toy can be used for interactive games by typically developing children. An even larger scope of usability for this product is for it to be used for testing multi-agent systems in different interactive contexts.

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