Designing Action-Characterizing Toy Blocks for Behavior Assessments

Xiyue Wang
Miteki Ishikawa
Kazuki Takashima
Research Institute of Electrical Communication
Tohoku University
Sendai, Japan
xwang@riec.tohoku.ac.jp
mishikawa@riec.tohoku.ac.jp
takashima@riec.tohoku.ac.jp

Tomoaki Adachi
Department of Education
Miyagi Gakuin Women's University
Sendai, Japan
adachi@miyagi.email.ne.jp

Ehud Sharlin
Department of Computer Science
University of Calgary
Calgary, Alberta, Canada
ehud@cpsc.ucalgary.ca

Patrick Finn
Computational Media Design
University of Calgary
Calgary, Alberta, Canada
pfinn@ucalgary.ca

Yoshifumi Kitamura
Research Institute of Electrical Communication
Tohoku University
Sendai, Japan
kitamura@riec.tohoku.ac.jp

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Abstract

Playing with toy blocks reveals patterns in children's play that are valuable for therapy and assessment. Following the 2011 Tohoku Earthquake and Tsunami in Japan, we witnessed young survivors expressing post-trauma stress in block play. Motivated by the limitations in assessing this behavior using traditional methods, our paper describes the design rationales of AssessBlocks, an action-characterizing system using smartwatch embedded toy blocks. Utilizing a smartwatch's Inertial Measurement Unit (IMU) and capacitive screen, a monitor is able to receive, visualize and document sequential and quantitative play actions that were empirically selected from a preliminary block therapy study on children's post-disaster stress. We also propose our vision of a multi-dimensional behavioral assessment system using actions obtained by AssessBlocks.

Author Keywords

Tangible user interface; toy blocks; children; post-trauma stress; PTSD; earthquake; tsunami; automated toy; play therapy; affective; behavior assessments.

ACM Classification Keywords

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

Figure 1. The appearance and inside look of AssessBlocks prototypes: the smartwatch is inserted into the block. Six copper strips that extended from each block surfaces are connected to the designed spots on watch screen, to ensure the watch receives touch information from another block and a hand's contact on the surfaces.

Introduction and Motivation

Playing with blocks has always been popular with children. Simple toy blocks have been used in classrooms and homes for educational and developmental purposes, and later in clinical settings to investigate children's behavior for play therapy and cognitive assessment [9,10]. Following the 2011 Tohoku Earthquake and Tsunami, in kindergartens and consulting centers in Sendai Japan (one of the hardest-hit areas), we observed new patterns of block play in high-risk Post Traumatic Stress Disorder (PTSD) children who experienced the earthquake and tsunami. For instance, young children under great stress and anxiety following the earthquake and tsunami had altered gameplay patterns including cycles of building block construction followed by intense destructive actions [1]. It was also observed that six months later both their PTSD symptoms and abnormal playing behaviors were alleviated. We speculated that specific actions in children's block play, such as stacking and destroying, might relate to their memory of the events, reflect emotional response towards those events, and, through play, help them process the experience and thus relieve stress and anxiety.

Unfortunately, monitoring and assessing children's feelings as connected to behavior require longitudinal, specialized, and detailed study. The traditional methods for assessing such behavior involves on-site or video-based observing, tagging and analyzing. These observation-based methods suffer from occlusion that blocks important information, and challenges related to subjective judgment. Inspired by the recent boom in smart toys that assist children's development and rehabilitation [5,12,13], we developed augmented toy blocks focused on formalizing assessments.

We propose our design rationale and vision for the multi-sensory block interface, AssessBlocks, which automatically characterize play actions for assessing specific behaviors in children's play. The design criteria determining which actions need to be detected and characterized is based on our findings during a two-year on-site study. We studied block therapy for preschool children's post-trauma stress (2.67-6.9 year old), in Sendai area after 2011 Tohoku Earthquake and Tsunami, using IMU (Inertial Measurement Unit) embedded toy blocks [1]. The critical actions found include hand-to-block interactions, such as standing up, holding, moving, shaking, and block-to-block interactions, such as stacking, adjacency, as well as patterns of breaking such as normal disassembling, free fall, and aggressive destruction. To meet the action characterization requirements, in AssessBlocks (Figure 1), each building block is equipped with a smartwatch inside. We utilize the IMU of the smartwatch to detect motion, as well as extend its capacitive screen to each surface of the block to detect touch. Using motion and touch information, the blocks can capture play patterns crucial for assessing abnormal behaviors and stress fluctuations. We output the actions and the graphic visualizations of actions in time-stamped sequences and quantitative counts, aiming to use those data to assess multi-dimensional states that assist or replace traditional assessments.

Background and Related Works

Toy blocks are popular with preschool children, and are credited with developing their spatial, emotional, social, intellectual, and intuitional skills [4]. Based on these traits, they are unique in play therapies and assessments [8, 9, 10]. Locally in Japan, toy blocks are one part of preschooler's annual examinations, testing their cognitive ability and stages of developmental [9]. Established block play therapies have also been used to treat social withdrawal and ADHD [8]. The traditional way of evaluating play therapy is based on an expert's observations on-site or from recorded videos [8,10]. These approaches suffer from occlusion and take considerable time and effort to gather partial data. A practical and effective assessment method would help to address these challenges.

Mental health research has revealed PTSD in children is a severe and complex problem. The catastrophic 2004 Asian Tsunami, 2008 Sichuan Earthquake and 2010 Haiti earthquake showed a prevalence of severe PTSD (12.4%-50%) and in some cases regressive development in children [2,3,7]. Pre-school children (3-6 years old) are particularly vulnerable to stress, since they have not fully developed linguistic expressions and an adaption to environments [2,3]. Recently, mental health supports have been deployed for children after disasters [2,3]. While a useful starting point, these interventions are short-term treatments, and lack the detailed research and analysis necessary to develop them, and test their effectiveness. An auditing and assessment interface that is easy to use, maintain, and compare over time, is needed.

Figure 2. Prototypes of the Bluetooth-IMU-sensor embedded blocks for the preliminary study.

Since tangible toys have been shown to be effective for children's learning [5], researchers have highlighted the potential of computer-aided tangibles. Jacoby proposed PlayCubes [6] that assessed children's construction ability using a tangible block called ActiveCube. Fan *et al.* showed that tangible letters can help dyslexic children learn reading and spelling [5]. Vonach *et al.* have designed "MediCubes" in which each cube embeds different, noninvasive sensors to measure young children's physiological parameters, capturing aspects such as pulse, temperature and skin condition during play [12]. Westeyn *et al*. created the augmented toy set, "Child'sPlay," using IMU and other sensors embedded in rings, blocks and rattles to support the automatic recording, recognition, and quantification of a child's play behaviors for retrospective analysis [13]. Child'sPlay, which suffers from difficulties when collecting and identifying interactions, provides useful evidence for the effectiveness of block-play approaches. Block-play provides a concise way to define, capture and analyze play action.

Preliminary Study

After observing PTSD-affected children's play behaviors, we designed a simple experiment to study block playing's effect on post-disaster stress relief, and its capability for assessing relevant play behavior [1]. We prototyped simple and sturdy augmented building blocks that held a Bluetooth IMU sensor[1] (Figure 2), which computed and output basic quantitative playing actions from one of the following play phases: moving time, holding time, standing time, standing count, placing count and accumulated acceleration. From 2013 to 2015, we recruited more than 52 pre-school children from 2.67 to 6.9 years old and divided them into two groups: a group who experienced the Tsunami, and one who did not. Presumably the former would be a higher stress group than the latter. We studied 20-minute physical play samples from individual children at their kindergartens using a set of twelve augmented blocks (Figure 3). We also assessed pre- and post-play stress level biomarkers, and concentration levels using on-site and recorded video observation [1].

[1] TSND121 http://www.atr-p.com/products/TSND121.html

a. Playing on a plane

b. Building the fence

c. Flicking the block

Figure 3. Abnormal behaviors

Categories	Play Actions
Individual State	stand-up, lay-down
Hand-to-block	hold, move, shake
Block-to-block	stack, adjacency, isolation
Disassembly	disassemble, free fall, aggressive

Table 1. Activities need to be characterized with blocks

The study revealed challenges to assessing stress levels from block play using statistical methods to assess the data outputs from the blocks. Changes in stress levels were highly correlated to children's observed concentration levels in post-trauma children. Our estimations of concentration levels using our block play parameters is potentially feasible but appeared to require additional parameters. While in an early stage, the preliminary study indicates the possibilities of an automated block system to assess children's concentration and use those markers to assess their degrees of stress.

We also found that our sequential data revealed important patterns related to complex emotional behavioral states. For example, some children played on flat surfaces after the built structures collapsed (Figure 3a). Children who exhibited this behavior tended to have an increased stress level after playing, which may be considered a sign of withdrawal behavior associated with PTSD [3]. We also discovered that some children who witnessed the tsunami showed fence building behaviors (Figure 3b). Some aggressive children had destructive behaviors such as flicking blocks (Figure 3c). Using time-stamped sequential events along with quantitative counts of these specific events, we may be able to capture complex states, including concentration level, gentle or destructive play, quiet or hyperactive play, and other one-dimensional indicators, as stepping-stones toward detailed stress assessment.

Critical Actions to Be Characterized

Based on the preliminary study, blocks designed to capture data for play analysis need to capture several types of data (Table 1). The first type is individual block states. This type includes which side a child put the block down, such as standing-up (small side on bottom) or laying-down (big side on bottom). The second type is hand-to-block interactions, including holding, moving, and shaking. The third type is the interactions in-between a group of blocks, in categories such as stacking, adjacency, or isolation from other blocks. The fourth and final category is the manner of disassembly, including normal, free fall, and aggressive destruction.

AssessBlocks Design

AssessBlocks contain a scalable number of "smart" building blocks each augmented with an IMU-embedded smartwatch and capacitive surface (Figure 1). While maintaining the appearance, volume and weight of traditional wood building blocks, it delivers data that can be processed, documented, and then provide a visualization of the children's sequential and quantitative play event outcomes. We plan to use these data sets to build multi-dimensional emotional behavior assessments, in categories for motor skills, educational development, and well-being, or emotional state.

System Design

The blocks are designed to be similar to commercially available toy blocks[2]. Two shapes were used: the 112*56*25mm "brick" and 56*56*25mm "half brick" which were 3D printed with ABS material (Figure 1). Each block carried a Sony Smartwatch 3 to ensure a robust and safe long-term data communication with the host computer via Wi-Fi. Without disrupting its normal function, we can plug the smartwatch into a block, connect the conductive copper strip to the screen of the

[2]Nichigan Original. Unpainted Wooden Blocks. http://www.nocorp.co.jp/mutoso/

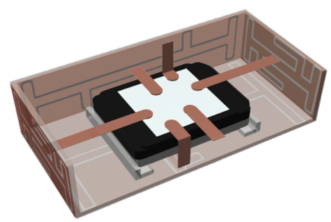

Figure 4. Each block's outside surface is connected to one designed spot on watch screen using copper tape (ochre colored).

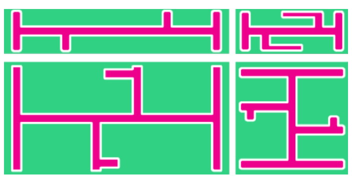

Figure 5. Conductive pattern: Magenta parts are connected to the smartwatch, while green parts are groundings.

Figure 6. The current visualization that provides a simple quantitative count(upper left and right) and sequential timeline (bottom).

watch using conductive ink (Figure 4), and run the watch-side application to communicate with the host. Currently we use six blocks, though the system is scalable in its Wi-Fi configuration.

In order to capture the desired actions, we designed the capacitive surface with conductive copper tape that detects touch from hands or other blocks (Figure 4). Our design making a surface capacitive is based on the mechanism of passive touch on capacitive screens proposed by Voelker *et al* [11]. On each surface of the block there are two conductive parts covered in copper tape: the connection that is connected to the surface of smartwatch and is shown in magenta in Figure 5, and the ground covering the remaining surface area represented in green. As Figure 5 shows, this pattern ensures the detection of a hand when a user touches the connection, and block-to-block contact when two blocks' connective components touch each other's ground elements.

Action-detection is achieved with the accelerometer and gyroscope of the IMU and the capacitive surface. We use a state machine structure, which switches between static and moving states with an acceleration threshold. In static state, we define the individual block states (i.e. standing, laying) using gravitational acceleration, and group states (i.e. stacking, adjacency, isolation) using touch information. In moving state, we define hand-block interaction when new touch information emerges, and differentiate moving, and shaking from holding using the acceleration threshold. We define disassembly as touch that stops entering moving state and differentiate the types of disassembly using the acceleration threshold and individual blocks' information.

Event Flow Visualization
We are currently working on an interface at the host side that visualizes the events (Figure 6). Using the visualization, the therapists, parents or kindergarten teachers can easily monitor the events in real-time, or later by reviewing play data. The data is saved in CSV files for subsequent steps of the analyses.

Future Direction

The next steps require interdisciplinary discussion and collaboration with medical and educational specialists, and data scientists. We aim to design a system that provides data categorized in the most relevant models for the key stakeholders in childhood education, assessment and health care.

Multidimensional Assessment using Recurrent Methods
We plan to break complex problems such as the conditions for PTSD, into sets of individual behavior pattern states such as concentration. Using sequential and quantitative actions as input, and the emotional behavior states determined by psychologists as output, we aim to model multi-dimensional emotional behavior states and visualize them (Figure 7) with statistical models. We anticipate recurrent machine learning models may perform well in this area of our research. The multi-dimensional assessments may enable the therapists, psychologists, teachers, and parents to view and compare a child's recognizable states and see the results of block play therapy over time quickly, easily, and in a visual display that supports conversation.

Working with Children
We look forward to continuing our work serving children through research. Items such as our use of copper surfaces may require reworking to adhere to important

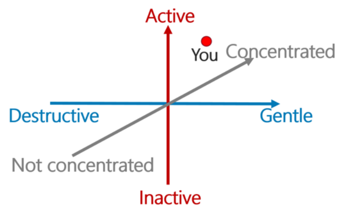

Figure 7. Proposed multi-dimensional visualization model: each user, after each session of play, will get an indicative location on this 3 or more dimensional representation estimated by AssessBlocks.

safety protocols. We are currently looking for food-safe yet conductive coatings to replace copper soon and are developing child-friendly prototypes for experiments. Given our positive experience working with children, and the past research that attests to similar results [1], we believe that extending our engagement to different groups of children is possible. We may work with children who suffer in natural and other kinds of disasters worldwide, but only with a careful study of best practices for such engagement.

Conclusion

In this work, we describe our design of the action-characterizing blocks, AssessBlocks, motivated by the impact of the 2011 Tohoku Earthquake and Tsunami on children in the region. Since children's post-trauma stress is a recognized problem, we look forward to developing our automated assessment tool to enhance children's wellbeing using toy blocks they enjoy.

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