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Sandtime: A Tangible Interaction Featured Sensory Play Installation For Children To Increase Social Connection

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Abstract

From the study of social-interaction enhanced gaming design, aimed at providing a public environment which supports tangible & social interactions among children, we designed *Sandtime. Sandtime* is a public installation designed to encourage such interaction. Using the Tangible Interaction Design approach, this gaming installation features collaborative play and social interactions under public context, where children can collaboratively interact with the virtual onscreen characters by manipulating physical objects. This design is based on the study of how interactive gaming facilities can help to ease anxiety and enhance social interactions among children. In this paper, we want to continue this line of research by exploring further the elements that can enhance such interaction experience. This paper focuses specifically on the sensory play and how it can help to facilitate social interaction.

Keywords: sensory play, tangible interaction, social anxiety.

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1. Introduction

Children's cognitive development has been proven to be a crucial part in education, enabling children to interpret, predict, and influence other people's emotional responses and behaviors [1]. Certainly, social interaction can have a positive impact on children's cognitive development in that it facilitates cooperating, sharing, communicating and development of 'operational thoughts' [2, 3]. However, the lack of interaction with peers appeared to relate to different psychological domains, causing social and emotional difficulties, which may negatively affect children's cognitive development [4].

In our previous research, we developed a prototype using multi-touch technology to illustrate how interactive group play can help facilitate social interaction among children [5]. Nevertheless, there are limitations in multi-touch technology itself, as researchers claimed that many problems emerge when multi-touch devices are used by very young children; their fine motor skills, such as pencil skills, construction skills, scissors skills and self care are not sufficiently developed [6].

To explore more possibilities in addressing these issues, in this paper, we present *Sandtime*, a hybrid facility combining digital screen and conventional physical manipulation that allows interactive and collaborative play. In particular, we concentrate on sensory tools for interaction

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that guide the user to explore and collaborate in a relatively natural way in the overall design of *Sandtime*.

Sensory play has the potential to encourage connection among children since tangible sensory feedback aids imitation and cooperation [7]. In our previous design *Seesaw*, we have focused on the elements that may facilitate social interaction, such as big screen and story-telling elements. We then considered constraints on children's ability to manipulate touch devices [6]. In the design of *Sandtime*, we wanted to involve more sensory elements to see if the physical object and the big screen can cooperate to provide a better user experience [8].

This study started with a survey of existing games related to Tangible Interaction, in order to see how these games actually transpose the concept of Tangible Interaction into social interactions. Comparing different theories about Tangible Interaction Design, Eva Hornecker's research provides insight into social aspects of Tangible Interaction which includes four mainstream themes as 'Tangible Manipulation', 'Spatial Interaction', 'Embodied Facilitation' and 'Expressive Representation' [9]. Since this analysis provides a fundamental understanding of social interaction as our major goal in the project, we conducted the case study based on her theory [Table 1].

Table 1. Case study based on Tangible Interaction Framework

	Tangible Manipulation (TM)			Spatial Interaction (SI)				Embodied Facilitation (EF)			Expressive Representation (ER)			
	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Climbing Wall (traditional)	√			√		√								
Imsound (2011)	√	√		√				√					√	√
Lite Brite: Super-Sized (2010)	√	√	√				√	√			√			√

(a) Haptic Direct Manipulation; (b) Lightweight Interaction; (c) Isomorph Effects; (d) Inhabited Space; (e) Configurable Materials; (f) Full-Body Interaction; (g) Non-fragmented Visibility; (h) Performative Action; (i) Embodied Constraints; (j) Multiple Access Points; (k)Tailored Representation; (l) Representational significance; (m) Externalization; (n) Perceived Coupling

Traditionally, children's gaming products such as Climbing Wall and Ball Pond encourage tangible interaction by providing space for Spatial Interaction (SI) and physical material for Tangible Manipulation (TM), and children can interact mainly with body movement (SI). However, in the play process, children have the freedom to play; their behavior is not directed by the system, which decreases their motivation to collaborate (EF). Therefore, we assume that more elements are still needed for traditional games to serve as a tool to develop social interaction.

With the flourishing of technology, some new products appear to provide more unique gaming experiences for children. Imsound enables children to manipulate the light by body movement (TM). The full-body interaction (SI) forms an essential part of this experience. This design is directing the group behavior by guiding them to interact with the light (EF), yet none of the lights in this system are connected with the others, which may lessen the interaction opportunity (EF) among children.

Lite Brite: Super-Sized, inspired by a traditional children's toy, creates a big screen for children to create patterns (TM). During the playing process, children can arrange the colour pen and display pattern on the screen (ER). Nevertheless, although the sheer size of the screen provides possibilities for group behavior (EF), without a central goal or main focus (EF), users may not feel compelled to collaborate. And for those who feel anxious, it is possible that they will stay in a corner and play by themselves.

2. Design rationale

Sensory-rich play is an inclusive way of encouraging problem solving, exploration and development, as the hands-on approach appeals to children with different thinking and learning styles [10]. Research has also shown that sensory integration techniques can help kids cope with overwhelming feelings by normalizing their feelings and behaviors [11].

When children are undergoing a sensory experience, there is a connection between neuro-system and behavior; with tangible manipulation, they develop an understanding towards life [12]. It is also proved that configuration of material objects affects social interaction by subtly directing group behavior, reinforcing social relations and group learning [9]. Each time a child encounters a sensory stimulus, they will develop nerve connections created from their own sensory experiences, which means that the richer their sensory experiences the stronger will be the patterns of learning, thought and creativity [10].

This project aims at developing interaction among children to facilitate their cognitive development. And because in previous research we have illustrated the basic components to facilitate social interaction for children, it is reasonable to not just explore the elements to facilitate interaction, but also improve the previous design into a better interaction tool. It is claimed that sensory play provides rich information input for children thereby enhancing their sense of engagement during cooperation process.

In the next section, we will present the design of *Sandtime* to further illustrate this point.

2. The overall design of *Sandtime*

The design of an interactive tool for children is meant to enable intuitive interactions and be easy to learn. In our previous design, we symbolized a playground game *Seesaw* using touch devices for children to interact (Fig. 1).

We developed *Sandtime* based on the research of *Seesaw* [3], with a special focus on social aspects in sensory play, intended to explore more design possibilities in this research spectrum. From the design of *Seesaw*, we have learned the characteristics and requirements of social anxiety for children, and discovered the potential for developing their social connection with interactive public installations. The overall understanding of the relevant technological potentials and limitations provides the prerequisites for the design of *Sandtime*.

Based on sensory play theory, we analyzed different elements in sensory play (Table 2) and incorporated them into this project.

Table 2. Examples of sensory-rich play

Common elements for sensory-rich play	
Sand	Leaves, twigs, moss etc
Water, bubbles, ice	Shaving foam, gloop, paint
Pepples and shells	Mud
A basket of household objects	String, fabric, buttons etc
Pastry, playdough, plasticine etc	Dried rice, pasta, lentils, seeds etc

Sandtime consists of three main components namely a sand tub, a projection screen and a computer centre as shown in Fig. 2. In this system, the major medium for children to interact with is sand. Whenever the children pour the sand into a funnel, they can gain immediate feedback from the screen.

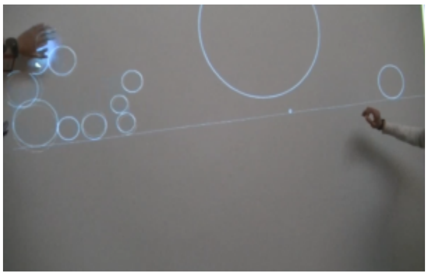

Figure 1. Phototype of *Seesaw*

Figure 2. Using *Sandtime*

3.1. Interaction approaches

Given time, children discover through their own independent learning that sand poured into a funnel will naturally flow through the holes. Besides, this system encourages players to not just interact with the screen, but also discover the "gaming themes" in the sand. Each gaming theme is attached to a physical component, which is buried in the sand tub, waiting for the users to discover. We try to incorporate the feature of sensory play into the discovering process, enabling children to feel the texture of the sand then gradually emerge themselves into the environment. The whole playing process symbolizes children's playing experience by the seaside. In this process, we try to create a sensory-rich environment which has the potential to encourage learning, exploration and creativity [10], so that the whole system is accessible and easy to operate for children.

3.2. Sensory input enrichment

When children pour the sand into the funnel, they can see the particle pattern generating on the screen. This process presents the transformation between tactile and visual sense, which is two of the major senses for children (Table 2). From this process, we want to create the linkage between different senses so as to strengthen sensory stimulation for children, so that their action and motor responses can be developed [10], providing the prerequisite for learning, thought and creative activities.

Table 3. Different senses

External senses	Internal senses
Visual(sight)	Vestibular(balance)
Olfactory(smell)	Proprioceptive(position in space)
Auditory(sound)	Kinesthetic(movement)
Tactile(touch)	Baric(weight)
Gustatory(taste)	Thermic(temperature)

To further enrich and vary sensory simulation in Sandtime, we present different storylines and different gaming scenarios (Table 4). Take Snowman storylines as an example: children can pour the sand to generate a snowman on the screen. Each of the scenarios provides various sensory elements for users, which correspond with the core elements in sensory-rich play (Table 3).

Table 4. Different storylines in *Sandtime*

Storyline	Sensory input	Elements for sensory output
Life of a tree		leaves, birds
Saving the whale	sand(Tactile)	bubbles, water
Snowman		snow, accessories for Snowman

Children in the anxious state tend to be socially avoidant and emotionally distracted [13]. Neuroscientists have identified a strong link between memory recollections and sensory elements such as sight, smell and touch senses [10], which have the potential to draw children's attention and help maintain focus [7]. By playing in the sand and experiencing various storylines, children develop the possibility to recollect the time when they were playing on the beach, which may help them to focus and ease anxious feelings.

3.4. Implementation

To implement our design, we use an Arduino Uno board to build the connection between projection screen and the physical object (Fig. 3). An Actionscript 3.0 (AS3) program is run on the computer, and connected to a digital screen, or projected on the wall. The sand funnel is set in front of the screen. Inside the funnel, we have inserted an Arduino board and sensors. When users pour the sand into the funnel, the data in the Arduino board will change and synchronize with AS3 program. Then the users can see that the physical object is transformed into a visual pattern on the screen.

The flowing speed of particles is consistent with natural objects, which is controlled by the following algorithm:

$$\mathrm{tempParticle.x} = \left(\mathrm{target1.x} - \mathrm{target1.}\frac{\mathrm{width}}{8}\right) + \left(\mathrm{Math.random()} * \mathrm{target1.}\frac{\mathrm{width}}{2}\right). \tag{1}$$

$$\mathrm{tempParticle.y} = \left(\mathrm{target1.y} - \mathrm{target1.}\frac{\mathrm{width}}{8}\right) + \left(\mathrm{Math.random()} * \mathrm{target1.}\frac{\mathrm{width}}{2}\right). \tag{2}$$

When the particles are generated, the start point and the end point have already been set so that the particles will flow towards a specific area on the screen.

To further mimic the actual particle effect, we use the laws of physics to vary the direction and rate of particle speed. Naturally, there will be friction and gravity restricting the rate of an object, so we also try to imitate this notion by gradually decreasing the speed.

$$\mathrm{tempParticle.rotation} = \mathrm{Math.random()} * 360. \tag{3}$$

$$\mathrm{tempParticle.rot} = \mathrm{Math.atan2(target1.y} - \mathrm{target2.y, target1.x} - \mathrm{target2.x)}. \tag{4}$$

$$\mathrm{tempParticle.xSpeed} = \mathrm{Math.cos(tempParticle.rot)} * \mathrm{radians\ /\ particleSpeed}. \tag{5}$$

$$\mathrm{tempParticle.ySpeed} = \mathrm{Math.sin(tempParticle.rot)} * \mathrm{radians\ /\ particleSpeed}. \tag{6}$$

Another element that we try to mimic is viscosity. When the particles come close to the end point, the speed will become zero, making it stick temporarily to that position. As the speed keeps increasing, the particle will move again after a while.

$$\begin{array}{l} \mathrm{if(tempParticle.hitTestObject(target))} \\ \{ \\ tempParticle.xSpeed = 0; \\ tempParticle.ySpeed = 0; \\ \} \end{array} \tag{7}$$

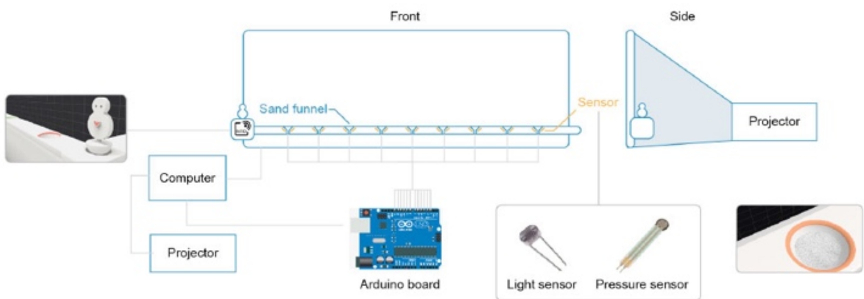

Figure 3. System structure of *Sandtime*

4. Evaluation

According to Jakob Nielsen's theory, researchers should be able to discover more than 75% of the usability issues from five users[14]. Based on Nielsen's theory, a user based evaluation of the proposed project was conducted with the participation of six users (three female and three males). The purpose of the evaluation was to determine whether the system was usable, and more specifically, to assess its ability to facilitate social interaction. One of the most important considerations during the evaluation procedure was to compare the sensory play system with a traditional digital screen system to examine the system's influence on users' social interactions. Each group was evaluated using the Evaluation of Social Interaction (ESI) to determine the baseline quality of social interaction [15]. The participants of the evaluation were provided with three different testing scenarios with or without sensory input [Table 5]. They are classified into three separate groups with two people in each group to conduct the testing. A quick introduction of the design was then provided in order to inform the participants about the basic concepts. Then the participants were requested to perform three different tasks including various interactive media and gaming elements. The first task requires the two users to use a button for operation. The second task is developed from the first task, adding the interactive elements in the gaming scenario. When the two users operate the system together, they will be able to gain visual feedbacks from the screen. The third task replaces the button with the sensory system for users to operate. Instead of using buttons, the users use sand to exploit the system. The operation process were recorded with camera and audio recorder for further analysis. Then after the testing, the users were asked few questions related to the usability of the system and their own preferences. After that, we further evaluated the social interaction factors based on ESI theory [Table 6]. By reviewing the videos, analyzing and observing the users, we were able to match the users' behaviors and characteristics with ESI theory, so that we could evaluate and compare the three system's functionality for social interaction development.

Table 5. Three different testings for the evaluation

External senses	Sensory Input	Interaction in the game
System 1	No	No
System 2	No	Yes
System 3	Yes	Yes

Table 6. Social interaction skills found on evaluation of social interaction (Fisher&Griswold, 2008)

Initiating and terminating social interaction:	
Approaches/Starts:	greeting and/or initiating interaction
Concludes/Disengages	ending interaction
Producing social interaction:	
Produces speech:	communicating using speech, or signed or augmentative messages
Gesticulates:	using gestures to communicate
Speaks fluently:	speaking tempo
Physically supporting social interaction:	
Turns towards:	turning body and face toward social partner
Looks:	making eye contact
Places self:	keeping personal space and distance
Touches:	making physical contact with social partner
Regulates:	controlling impulses and behaviors
Shaping content of social interaction:	
Questions:	requesting information or opinion
Replies:	providing relevant response and detail to questions and comments
Discloses:	sharing personal information, opinions, and feelings about oneself or others
Expresses emotion:	displaying affect and emotions
Disagrees:	disagreeing with social partner's stated suggestions or stated point of view
Thanks:	acknowledging information, compliments, help or material objects

The questions for user preference clearly show that users are mostly satisfied with the usability of the first system whereas they think that the third system is most interesting and engaging. Based on observation of the users from the recorded videos, we developed Table 7 to summarize the users' social interaction behaviors during the playing process based on ESI theory. Each number on the table represents the time that the social interaction behaviour happens. For instance, at the time of 0:17, 0:35, 0:39 and 01:19, speech was produced by the users. Then after observing and classifying the different behaviors of the users, we developed a graph (Fig. 4) to visualize the happening times of the social interaction behaviors for the three testing groups.

Table 7. Analysis results based on evaluation of social interaction theory

Test / Group Social skill taxonomy		Group1			Group2			Group3		
		Test1	Test2	Test3	Test1	Test2	Test3	Test1	Test2	Test3
Initiating and terminating social interaction	Approaches starts	0:07	00:04	00:03	00:03	00:03	00:04	00:07	00:02	00:07
	Concludes disengages									
Producing social interaction	Produces speech	00:17 00:35 00:39 01:19		00:03 00:16 00:37	00:51	00:14 00:22	00:04 00:08 00:14 01:07 01:14 01:21 01:28	00:07 00:41 01:11	00:07 00:10 00:15 00:18	00:07 00:31 00:33 00:40 01:30

It is observed from the graph that compared with the previous two systems, the pattern in the third system is relatively dynamic, which means the social interaction behaviors in the third system is more active. The users in the third system experienced an enhancement in the frequency and the variety of the social behaviors. Therefore, us assume that sensory play generates more interaction possibilities. Except for the common verbal communication, in the third system, the users developed various interactions regarding body gestures and eye contact[Table 6].

We can also observe from Fig.4 that the interactive elements in the game provide the possibilities for sustained playing. As can be seen in the figure, the curves for the second and third tests remain at a higher level than the first testing, which symbolizes sustained connection with the system. Besides, the overall factor for emotional expression in the third testing is the highest among all the three user groups.

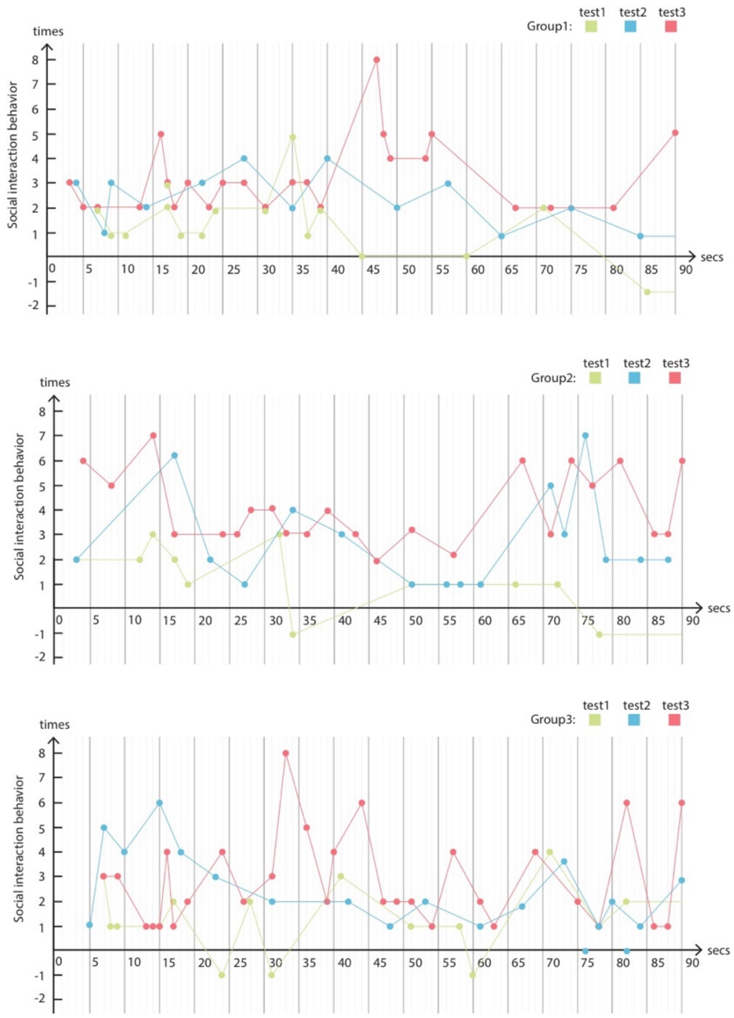

Figure 4. Analytic graph for the three testing groups

5. Discussion and future work

In this paper, we have described the architecture and development of an interactive system. We have explored and investigated the possibilities of incorporating tangible elements into the system to facilitate collaborative behaviors. The system is expected to become an effective tool for children to build connection since it provides rich sensory information.

From the end user's perspective, the conducted evaluation has proven that systems with interactive elements facilitate constant playing behaviors between the users. Furthermore, the analysis based on ESI theory [Table 6] indicates that sensory system enhances the variety in social interaction behaviors. We assume that sensory elements, with the possibilities to improve playing and social interaction behavior, add value to the pure digital screen play.

For our future work, we are planning to improve *Sandtime* by creating more gaming scenarios and developing various interaction methods to further examine the functionality of sensory play. The following subsections discuss some possible directions for further development.

5.1. The development of the game levels

Games with levels or parts that have different degrees of difficulty can facilitate engagement among the children [16]. Yet what we also concerned with is how to enrich the gaming experience without affecting the group playing experience. Children prefer switching games frequently when they play alone, but they do not switch among games as much when they are in a group [16]. So we may need to further consider the balance between system complexity and children group engagement.

In the future, we are planning to develop the gaming system into a system with different difficulty levels, so that children of different ages will be able to select the level that is most suitable to play. Therefore, *Sandtime* will be able to facilitate social behaviors in a more effective way.

5.2. The development of the tangible elements

Sand is the main medium for the users to interact with in *Sandtime* system. In order to enhance the sensory experience in this system, it is reasonable to think about different sensory media, so that this system will be able to adapt to different using environments.

Besides, enriching the sensory elements also provides possibilities for the users to explore reminiscences. For instance, sand facilitates the memory in the beach, whereas the other sensory elements, such as snow, may stimulate the memory of building a snowman. All those various tangible features may enhance the possibilities for engaging users thus facilitating their social interaction.

5.3. The Improvement of the evaluation method

Furthermore, in terms of exploitation, it is important to test the sensory system in the context of different public environments such as hospital waiting rooms, airports and amusement parks.

User's emotions and needs vary a lot in different contexts, thereby conducting the test in various contexts helps better evaluate the usability of the system. Then the system can be improved based on the feedback from different experiments.

To further examine the usability of *Sandtime*, we may need to develop another portable version of the prototype, which enables us to conduct testing in public space effectively. What we are interested in is the added value provided by tangible elements, and how those elements can affect children's behavior and cognitive development.

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