Sandtime: A Tangible Interaction Featured Gaming Installation to Encourage Social Interaction Among Children

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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 in-screen 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 sensory play and how it can help to facilitate social interaction.

Keywords: Sensory play · Tangible interaction · Social anxiety

1 Introduction

Anxiety disorders in young people are one of the most common forms of psychopathology and it was estimated that 13% of children and teens have anxiety disorders [1]. In terms of emotional functioning, children with high levels of social anxiety occasionally perceive themselves as less socially accepted compared with their less anxious counterparts, becoming socially avoidant and inhibited [2].

In our previous research, we developed a prototype using multi-touch technology to illustrate how interactive group play can help to facilitate social interaction among children [3]. Nevertheless, there are limitations, as researchers claimed that many problems emerge when multi-touch devices are used by very young children in that their fine motor skills are not sufficiently developed [4]. To explore more possibilities in this line of research, 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 that guide the user to explore and collaborate in a relatively natural way. We also describe the overall design of *Sandtime*.

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Sensory play has the potential to encourage connection among children since tangible sensory feedback aids imitation and cooperation [5]. Yet considering the overall design goal of this project, for those who tend to be anxious and emotionally inhibited [6], it is reasonable to provide more interaction possibilities so as to lower their access thresholds. In our previous design Seesaw, we focused on the elements that may facilitate social interaction, such as big screen and story-telling elements. Then consider-ing constraints on children's ability to manipulate touch devices [4], in the design of *Sandtime*, we wanted to involve more sensory elements to see if physical object and big screen can cooperate to provide a better user experience [7].

We start our study with a survey of existing games related to tangible interaction, in order to see how these games actually transpose tangible interaction concept into social interactions. Comparing different theories about tangible interaction design, Eva Hornecker's research provides insight for social aspects of tangible interaction which includes four mainstream themes as 'Tangible Manipulation', 'Spatial Interaction', 'Embodied Facilitation' and 'Expressive Representation' [8]. 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 as they wish, so their behavior is not directed by the product for Embodied Facilitation (EF), 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 (Fig. 1). 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 toy, creates a big screen for children to create patterns (TM). During the playing process, children can arrange the color 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.

Fig. 1. (a) (left) Children playing with Climbing Wall, (b) (middle) Playing environment of Imsound, (c) (right) The usage of Lite Brite: Super-Sized

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 [9]. Research has also showed that sensory integration techniques can help kids cope with overwhelming feelings by normalizing their feelings and behaviors [10].

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 [11]. It is also proved that configuration of material objects affect social interaction by subtly directing group behaviour, reinforcing social relations and group learning [8]. 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 for learning, thought and creativity [9].

Since this project aims to develop interaction among children who tend to develop social anxiety, we also need to consider whether sensory play can cater for the requirements of this typical user group. It is argued that expanding tabletop applications with tangible interaction can make computers accessible to children with cerebral palsy and children with social disorders [4]. And tangible interaction has proved to have a positive effect for both normal children and children with cognitive disabilities [6]. Based on the research mentioned above, it is possible for us to assume the potential for sensory play to facilitate social interaction among anxious children. In the next section, we will present the design of *Sandtime* to further illustrate this point.

3 The Overall Design of *Sandtime*

The design of an interactive tool for children is meant to be straightforward and easy to understand. In our previous design, we symbolized a playground game "Seesaw" using touch devices for children to interact (Fig. 2).

We developed *Sandtime* based on the research of Seesaw [3], with a special focus on social aspects in sensory play, to see 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 public interactive 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 center as shown in Fig. 3. 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.

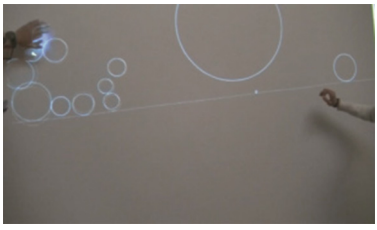

Fig. 2. Phototype of *Seesaw*

Fig. 3. Using of *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 ocean. In this process, we try to create a sensory-rich environment which has the potential to encourage learning, exploration and creativity [9], so that the whole system is accessible and easy to operate for children.

3.2 Sensory Input Enrichment

When children pour the sand into 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 simulation for children, thus their action and motor responses can be developed [9], providing the prerequisite for learning, thought and creativity activities.

Table 3. Different senses

External senses	Internal senses
Visual(sight)	Vestibular(balance)
Olfactory(smell)	Proprioceptive(position in space)
Auditory(sound)	Kinaesthetic(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 is 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	sand(Tactile)	leaves, birds
Saving the whale		bubbles, water
Snowman		snow, accessories for snowman

Children in anxious state tend to be socially avoidant and emotionally distracted [12]. Neuroscientists have identified a strong link between memory recollections and sensory elements such as sight, smell and touch senses [9], which have the potential to draw children's attention and help maintain focus [5]. By playing in the sand and experiencing various storylines, children develop the possibility to recollect the time when they were playing in the beach, which may help them to focus and ease anxious feelings.

3.3 Collaborative and Competitive Behavior

Through the playing with sand, children share the same physical object and feel their fellow players' presence, which makes it easier to establish joint attention [5]. Yet to develop for children in anxious state, it is reasonable to provide more interaction chances in this system.

Sandtime also encourages children to collaborate and compete. The two users who are next to each other can pour the sand together to create a new object (Fig. 3). For instance, in The life of a tree, they can create a bird, which will fly actively onto the tree. And at the same time, the two players can cooperate to compete with the other groups.

During the collaborative and competitive process, children are connected with each other physically and emotionally, focusing on the same task. Since it is said that attention control condition would facilitate untrained positive or neutral social behaviors as well as peer acceptance, we assume this design will further develop the social interaction between children and their counterparts.

3.4 Implementation

Technically, we use arduino to build the connection between projection screen and physical object (Fig. 4). 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.

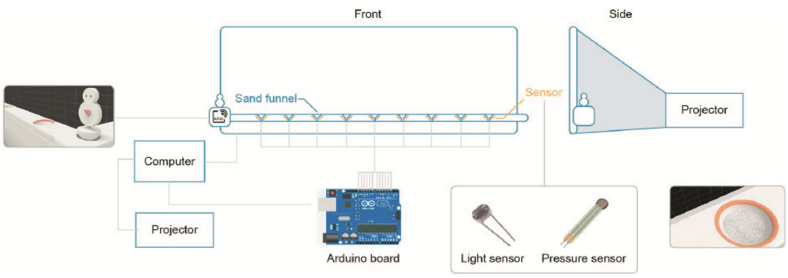

Fig. 4. System structure of *Sandtime*

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

```
tempParticle.x = (target1.x - target1.width/8) +
(Math.random()*target1.width/2);
tempParticle.y = (target1.y - target1.height/8) +
(Math.random() * target1.height/2);
```

When the particles are generated, the start point and the end point have already been set, so the particles will flow towards a certain 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 speed of an object, so we also try to imitate this notion by gradually decrease the speed.

```
tempParticle.rotation = Math.random()*360;
tempParticle.rot = Math.atan2(target1.y - target2.y, tar-
get1.x - target2.x);

tempParticle.xSpeed = Math.cos(tempParticle.rot) * radi-
ans / particleSpeed;
tempParticle.ySpeed = Math.sin(tempParticle.rot) * radi-
ans / particleSpeed;
```

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.

```
if(tempParticle.hitTestObject(target))
{
  tempParticle.xSpeed=0;
  tempParticle.ySpeed=0;
}
```

4 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.

For our future work, we are looking forward to improve *Sandtime*, such as by creating more storylines and conducting concrete evaluations.

Following are some possible directions for further development, given that research has proved the positive influence of gaming complexity for children. It is said that games including levels or parts that have different degrees of difficulty can facilitate engagement among the children [13]. 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 played alone, but they do not switch among games as much when they are in a group [13]. So we may need to further consider the balance between system complexity and children group engagement.

In this paper we presented a sensory facility for children to interact, yet what we are still not sure of is whether this design is a superior option for children to choose,

compared with touch devices. To further examine the usability of *Sandtime*, we may need to develop another prototype, getting rid of tangible elements for further evaluation. What we are interested in is the added value provided by tangible elements, and how those elements can affect children's behavior.

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