Playful Tray: Adopting Ubicomp and Persuasive Techniques into Play-Based Occupational Therapy for Reducing Poor Eating Behavior in Young Children

Jin-Ling Lo[1,2], Tung-yun Lin[3], Hao-hua Chu[3,4], Hsi-Chin Chou[1], Jen-hao Chen[4], Jane Yung-jen Hsu[3,4], and Polly Huang[3,5]

[1] School of Occupational Therapy
College of Medicine
[2] Department of Physical Medicine and Rehabilitation
National Taiwan University Hospital
[3] Graduate Institute of Networking and Multimedia
[4] Department of Computer Science and Information Engineering
[5] Department of Electrical Engineering
National Taiwan University
hchu@csie.ntu.edu.tw

Abstract. This study has created the Playful Tray that adopts Ubicomp and persuasive techniques into play-based occupational therapy for reducing poor eating behavior in young children after they reached their self-feeding age. The design of the Playful Tray reinforces active participation of children in the activity of eating by integrating digital play with eating. Results of a pilot user study suggest that the Playful Tray may improve child meal completion time and reduce negative power play interactions between parents and children, resulting in an improved family mealtime experience.

1 Introduction

Recently, many Ubicomp researchers have been working on applying digital technology to modify human behavior [1] [2] [3]. This area is known as *persuasive computing* [4]. From a computing perspective, persuasive computing involves designing and developing digital technology that not only can automatically sense and track behavior, but can also engage people via *intelligent interaction* to motivate or influence their behavior. From an occupational therapist perspective, persuasive computing involves extending the reach of occupational therapists from their treatment clinic into the actual living environment of a client, enabling the therapists to utilize Ubicomp technology to implement an effective behavior intervention program at the place where the client's target behavior occurs and when the treatment is most effective.

This work targets *mealtime behavior*, one of the most frequently cited problems by parents of young children [5]. Despite nutritional concerns, spending excessive time to eat a meal affects the participation of children in daily school and family routines, and often contributes to negative parent-child interaction during mealtime [6]. For example, poor eating habits at home by children can cause stressful confrontations

J. Krumm et al. (Eds.): UbiComp 2007, LNCS 4717, pp. 38–55, 2007.

with parents, often taking the form of a *power play* involving mental persistence and pitting parental persuasion against unrelenting refusal from the children. At school, children who eat lunch slowly are likely to experience frustration resulting from the disapproving looks of teachers or the scorn of their peers. Delayed meal completion may also reduce the time available to children to engage in after-lunch activities. To address this eating behavior issue, this study has designed and implemented the Playful Tray as a tool to assist occupational therapists and parents in reducing poor eating behavior in young children. This tool can be used either at home or in school. A pilot user study where autistic and non-autistic children with mealtime problems participated suggested that the Playful Tray may improve child meal completion time when compared to traditional parental verbal persuasion. Results also suggest that the Playful Tray may reduce negative power play interactions between parents and children.

Fig. 1. On the left, a young child is performing her imitation skit and not paying attention to eating her food. By the time her parents are done with their meals, her meal is hardly touched. By then, her parent will become angry with her. Her parent's angry voice will also wipe out her appetite. On the right, this young child is actively eating to interact with the Playful Tray.

The Playful Tray is embedded with an interactive game played over a weight-sensitive tray surface, which can recognize and track the natural eating actions of children in real time. Child eating actions are then used as game inputs. As shown in Fig. 1, engaging children in this fun interactive game motivates the children to change their eating behavior. This design connects and integrates the fun part (coming from the digital game activity) with the activity of eating. We believe that this is the main reason why the Playful Tray may be effective in reducing poor eating behavior in young children.

The tray design is based on learning theories and the key components of *playfulness* [7] [8], including intrinsic motivation, internal control, and suspension of reality described in more detail in Section 2. The design reinforces active participation of children in the activity of eating by integrating digital play with eating, thus making mealtimes more enjoyable for both parents and children. Additionally, the flexibility of the digital game control enables occupational therapists to easily grade the challenge to match the ability of the child. For example, changing the weight sensibility of the tray affects the size of the bites required to trigger a game response.

Traditional eating behavior interventions depend heavily on parents actively modifying their behaviors and interactions with children during mealtimes [9]. For example, therapists seek to modify parent behaviors by teaching mealtime related parenting skills via didactic instruction, modeling, role playing, and behavioral rehearsal and structured home programs. We would like to clarify the intention of the Playful Tray is not to replace occupational therapists and the training they provide to parents on how to interact with young children, but to be used as an assistive tool that supplements the skills taught by occupational therapists. This work hypothesizes that by using the Playful Tray, it can assist parents to enhance children's motivation to eat. Results of a pilot user study involving the use of the tray by young children with eating problems suggested that the Playful Tray may address these hypotheses.

The remainder of this paper is organized as follows. Section 2 provides an overview of play-based feeding behavior intervention. Section 3 then states the design considerations for the playful tray. Next, Section 4 presents the design and implementation. Section 5 then describes the user studies and results. Subsequently, Section 6 discusses related work. Finally, Section 7 presents our conclusions and future work.

2 Play-Based Feeding Behavior Intervention

"Play is a child's way of learning and an outlet for his innate need of activity" [10]. For a child, any activity can be turned into a game. Children often engage actively and fully in an activity only if that activity includes the critical ingredients of play. Therefore, traditionally, pediatric occupational therapists (OTs) frequently leverage the desire of children to play as an effective means to cultivate the general skills and abilities needed to perform their functional activities. This is an indirect approach of training children in general skills via play activities, rather than directly targeting specific functional activities. For example, by feeding dolls or scooping play dough from one container to the other, children can improve their fine motor skills and the eye-hand coordination required for eating. However, this indirect approach suffers from the problem that improvements in perceptual-motor skills do not guarantee improved performance in the target functional activity, i.e., self-feeding. A more direct approach is to make the target functional activity playful to engage the child into active participation.

According to the model of human occupation (MOHO) [11], an occupational behavior such as eating is the result of the organization of three subsystems of a person: volition, mind-brain-body performance and habituation. To develop children's functional ability and become a part of their daily routines, they first need to have motivation to participate in the target behavior and sufficient physical and mental functions to meet the need of performing the target activity. Based on MOHO, this work developed a play-based occupational therapy model for designing the playful tray shown in Fig. 2. In this model, the three subsystems are facilitated by applying theories of playfulness and reinforcement into the design. According to theories of play and playfulness [8], play comprises three primary elements: *intrinsic motivation, internal control*, and *suspension of reality*. Intrinsic motivation means that the individual pays more attention to the process than to the product or outcome. It is the activity itself rather than its consequences that attracts the individual to active participation. Moreover, internal control is defined as individuals being in charge of *their* actions and at least some aspects of the activity outcome. Suspension of reality refers to the pretend quality of play. The three elements of play comprise the foundation of activity design. To successfully induce active child participation in an activity, activity designs should provide a strategy to elevate the degree of intrinsic motivation (less extrinsic motivation), internal control (less external control), and suspension of reality. Mind-brain-body performance refers to an individual's physical and cognitive capability to perform a target activity. Introducing digital play into an activity design should avoid increasing the physical and cognitive difficulty levels beyond those in the target activity. For example, the digital play in our Playful Tray adopts the strategy of using natural eating actions, which all children know how to do, to play a game.

On the other hand, acquisitional theory views behavior as a response to an environment [12]. The environment thus either reinforces behavior or fails to provide positive reinforcement by instead giving no reinforcement at all. Positive reinforcement strengthens behavior by rewarding the desired behavioral response. Previous studies [7] have shown that partial reinforcement is the strongest form of reinforcement in shaping behavior. Partial reinforcement is defined as reinforcement only given on some occasions when the behavior occurs, meaning there is no discernible pattern regarding when the reinforcement will take place. To strengthen desirable behavior, the design should employ the principle of partial reinforcement embedded in an activity. Through partial reinforcement, the desired behavior can be internalized and become a habit.

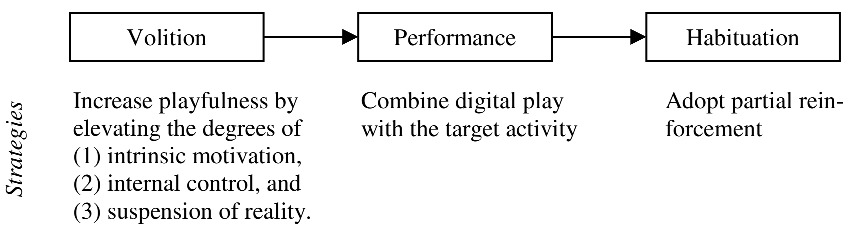


Fig. 2. Our play-based occupational therapy model

Feeding problems can occur in children with normal development and those with developmental problems. For children with significant developmental problems, feeding problems are treated seriously because the treatment outcome significantly affects child development [13]. However, for children with normal development or mild developmental problems, such as those with Asperger's Syndrome or High Function Autism, feeding problems are generally ignored or underscored. The most common complaint regarding mealtime behavior for these children is eating too slowly. Such problems create stress for caregivers, often the children's parents, negatively impacting the parent-child relationship. Therefore, this study targeted the second group of children and applied the play-based occupational therapy model to design a playful tray for them with the goal of improving their eating pace and reducing their maladaptive behavior.

3 Playful Tray Design Considerations

Based on the play-based occupational therapy model described above, this work has identified the following four main design considerations for the proposed playful tray: (1) *attention* split between game playing and eating activities, (2) *enjoyment* to encourage intrinsic motivation of children, (3) *engagement* to connect digital playfulness to active participation in the target activity of eating, and (4) *control* to give children choices in determining game outcome.

The first design consideration is the degree to which a child pays attention to the digital interaction. Since children need to focus their attention on feeding activity during mealtimes, introducing a digital game will inevitably divert some of their attention away from the eating activity. Because the use of the digital game is intended to motivate active child participation in the eating activity, the digital game design should not draw too much attention away from the eating activity and thus lead to the undesirable result of digital playing overtaking or distracting eating. That is, a game design should bring in just enough digital interactivity to maintain the interest of children in the eating activity. The game thus should avoid fast-moving, excessively fancy animation or frequent input and output.

The second design consideration is enjoyment. The digital game activity must bring sufficient enjoyment and pleasure to children to attract their active participation in eating. Motivation to perform an activity usually comes from two sources: external rewards and enjoyment of the activity itself. External rewards mean the accompanying benefit of performing an activity. When the rewards seem unattractive to a person, he/she will feel a lack of motivation to participate in the activity. On the other hand, if an activity is playful, i.e., with high levels of the three elements of play, carrying out the activity itself will be enjoyable and self-reinforced rather than reinforced by external rewards [14]. This study used a game design based on self-reinforcement.

The third design consideration is engagement. Since target users are young children and most young children are not capable of operating digital devices, the game design relies on using the *natural* eating actions of children as game input. Because eating is the target activity, once children are attracted to the game, they find that they have to eat to continue playing. Through this engagement design, this work links fun (from the digital game) with eating.

The fourth design consideration is control. Control refers to the opportunities for children to make choices and decisions during a game. The game design allows children to choose from a selection of characters and determine their eating pace.

Two further design considerations are presented below:

- It is important to minimize the change on the lunch tableware accustomed to young children during their normal eating routines at home or in schools. Hiding digital components beneath a tray surface prevented the installed digital hardware from adversely affecting the normal eating of the children.
- Given the limited cognitive level of young children, the design of the interactive game must be simple enough for them to understand and attractive enough to maintain their attention.

4 Playful Tray Design and Implementation

Two prototypes of playful trays were created. Fig. 3 shows the initial prototype, called the Coloring Game Tray. The design of this tray incorporates a dining surface of 30x45 cm^2, divided into a matrix of 2x3 cells. Besides the middle top cell onto which the game is projected, each of the other five cells contains a weighing sensor underneath the cell plate to detect eating events. The eating events are then fed as inputs to a coloring game played on the middle top cell. Each food item corresponds to a specific crayon color. When a child eats a specific food item, the corresponding color is drawn on a cartoon character selected by the child. To make the selected cartoon character colorful, the child thus should be motivated to eat and finish all food items on the table, including disliked items.

Fig. 3. Initial playful tray prototype called the Coloring Game Tray

A preliminary pilot user study of the Coloring Game Tray reported in [15] identified four problems with the initial design. (1) Some children felt extreme frustration when the cartoon character did not look colorful and happy at the end of the game, and refused to play again. (2) Although some children were attracted to the coloring game the first few times they played with it, they quickly became bored because the color mappings never changed. (3) Some children paid so much attention to playing the digital game that they became distracted from eating properly. (4) Some children ate too quickly as they became impatient to see their favorite cartoon characters fully colored.

Based on the problems of the initial prototype, a second, simpler prototype was created, called the Racing Game Tray. Although the revised design and implementation are simpler than the initial prototype, results of a pilot user study (discussed below in Section 5) suggest that the Racing Game Tray is more effective than the Coloring Game Tray.

4.1 Single-Cell Tray

The Racing Game Tray prototype is shown in Fig. 4. The dimensions of the tray are 33 cm x 31cm x 3.5cm. The top of the tray is embedded with a small palm-top PC containing a touch-screen LCD showing the racing game. The tray uses only one weighing sensor to detect child eating behavior. This weighing sensor is placed below the slightly lower rectangular area on the tray, and has a bowl positioned directly above it. The weighing sensor can detect and recognize child eating actions and the weight of food consumed from the bowl during each eating action. Since children are likely to touch all areas of the tray, the weight sensing area was just large enough to fit a bowl, minimizing the chance of touching of the tray interfering with the weight readings on the weight sensing area.

Fig. 4. The revised playful tray prototype, called the Racing Game Tray

The system architecture is shown in Fig. 5. Child eating activity was first sensed by the weight sensing surface, then recognized via the *Weight Change Detector*. The weight change detector performs one task: reporting *Weight-Change* events involving the food container by filtering out noises from the stream of weight samples. These weight change events include the amount (weight) of food consumed. A weight decrease event is generated each time the weight of the bowl decreases.

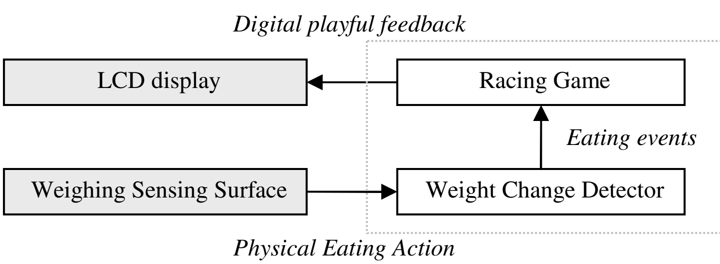


Fig. 5. System architecture

Through observations of young children taking meals in our clinic and interviews with their parents, we have realized that young children can exhibit a wide variety of eating and non-eating behaviors during meal times. As a result, not all weight decrease events will in fact be eating actions. For example, children may play with their food by hitting the bowl with their hands or utensils, scoop up some food and then put it back without eating it or after taking only a tiny bite, they may press their hands into the bowl, they may knock hard or push the tray, and so on. Since these non-eating actions affect the weight readings, they can confuse the system in recognizing some of these non-eating actions as valid eating actions. As a result, some *non-eating actions* may receive the same positive reinforcement and encouragement from the digital game as valid eating actions. To give an example, children may first press their hands into the bowl, creating a weight increase reading, and then lift their hands away from the bowl, creating a weight decrease reading. Because of the potential for these and other similar behaviors, simply using relative weight decrease over time will not accurately identify poor eating behaviors.

To address this issue, eating actions are recognized by calculating the *absolute weight decrease over time* value (Δw_t^{abs}), defined as follows:

$$\Delta w_t^{abs} = w_t - min\ (w_{1..t-1})\ . \tag{1}$$

w_t denotes the current weight reading, and $min\ (w_{1..t-1})$ represents the accumulative minimum weight reading from the start of the meal to the last reading. All relative weight decreases or increases are ignored. This method was found to be effective in filtering out most non-eating actions, though at the cost of missing some good eating actions. However, this tradeoff is acceptable given that encouraging bad eating actions is worse than missing feedback to some valid eating actions. Notably, this method can fail in one case, namely when a child picks up the entire bowl from the tray, causing the minimum weight reading to reach zero and creating a situation in which good eating actions can no longer be detected. To address this problem, the bowl is taped and fixed to the tray, preventing a child from easily lifting it up. Another situation can involve a child scooping up food and then putting it back without eating it. Although our system would incorrectly recognize this non-eating action as a valid eating event the first time it occurred, repeating the action would have no effect. When applied to young children in the pilot study discussed below, analyzing the logged eating events and the taped videos shows that this method can achieve accuracy of 70~80 % in recognizing valid eating actions, and only very rarely incorrectly recognizes bad eating actions as good ones. These eating actions are then used as inputs to the *racing game* described below.

4.2 The Racing Game

Screenshots for the racing game are shown in Fig. 6. Upon detecting each eating action, one of the characters would race one step forward to the right. The character is selected based on a random probability similar to a slot machine. The rationale for applying this randomness in this game is to adopt the partial reinforcement described in Section 2, which is the strongest form of reinforcement in shaping behavior. The distance traveled is fixed regardless of the size of the weight change from each eating action. The right screenshot in Fig. 6 shows the state of a race after a number of eating actions. When starting a meal, a child selects a favorite cartoon character, marked under the red arrow in the screenshot of Fig. 6. When the child finishes all of the food in the bowl, the game ends and the character that has traveled the furthest distance to the right wins. When a child eats too quickly (that is, the time interval between subsequent eating actions is smaller than a pre-defined *eating-too-quick* value), a

Fig. 6. Screen shots for the Racing Game Tray

notification is sent to the child to slow down his/her eating since eating will temporarily no longer be rewarded. This system prevents excessively aggressive eating.

The racing game design strategies follow the play-based occupational therapy model described in Section 2. It adopts partial reinforcement strategy by randomly selecting a character to race one step forward after each eating action. Due to the effect of partial reinforcement, children are motivated to continue eating to try and help their character win the game. The game motivation and enjoyment confirm to the self-reinforced strategy. This game also provides internal control to children, allowing them to choose a favorite cartoon character to compete in the race. The pace of the game is also controlled by children's eating behavior. Using the *natural* eating actions of children as inputs to the game is *critical* because eating is the target activity. Once children become attracted to the playful digital game, they find that they must eat to continue playing. Compared to video games, the racing game diverts only a moderate portion of the child's attention away from eating. This design connects and integrates the fun part (coming from the digital game activity) with the activity of eating.

5 Pilot User Studies and Results

In this section, we describe the details of a pilot study.

Participants. The participants comprised four child-parent pairs: three were recruited from the occupational therapy clinic of a teaching hospital; one was recruited by an office colleague. The four children were 4 to 7 years old. All participants are Taiwanese living in Taiwan. These four child-parent pairs are referred to here as *A, B, C*, and *D*. Children *A* and *B* were diagnosed with Asperger's syndrome, child *C* had high function autism, and child *D* had no specific diagnosis. The common complaint regarding mealtime for all parent participants was long meals, ranging from near 30 minutes to over one hour, after the children reached the age of self-feeding.

Procedure and measures. This study was conducted in Taipei, Taiwan. An occupational therapist first administered a semi-structured interview. A parent-report, Children's Mealtime Behavior Checklist (shown in Appendix A), was filled out and followed by an interview to clarify behavioral details. This checklist, including 19 types of child behaviors and nine types of parent behaviors, was modified from the Behavioral Pediatrics Feeding Assessment Scale [16] and the Children's Eating

Behavior Questionnaire [17]. After receiving informed consent from parents, the child/parent pair were: (1) invited to take their meals at our clinic or an investigator was dispatched to the home of the pair during their mealtime to record their eating activities before using the Racing Game Tray, then (2) another mealtime appointment was made within one week to record their eating activities using the Racing Game Tray. As for the locations of the studies, the Child *D*'s study was conducted at her home, and other studies were conducted in the clinic. The served meals were familiar, traditional Chinese food prepared by the children's parents, consisting of mostly rice mixed with vegetables and meat. The mealtime episodes were videotaped via a video camera set in the same room. After setting up the video camera and/or Racing Game Tray, the parent and the child were left in the room by themselves until the meal was finished. To perform a fair comparison on child eating behavior, approximately the same amount of food was served during the meals with and without the Racing Game Tray.

An eating behavior coding system, as listed in Appendix B, was modified from the system created by Moore *et al.* [18]. The coding system consists of three behavioral categories: *active feeding*, *interaction*, and *social behaviors*. Active feeding refers to child active eating behavior or any related behavior. Furthermore, interaction refers to actively initiated behavior and the synchronous responsive behavior of the feeding partner. Finally, social behavior only refers to the behavior toward the feeding partner but not that directly related to feeding. In the active feeding and interaction categories, behavior was classified as either positive or negative: positive behavior describes behavior associated with promotion of self-feeding, whereas negative behavior describes behavior associated with aversion, intrusion, or interruption of self-feeding. The codes are mutually exclusive. Appendix B lists the details of the codes together with behavioral examples.

The mealtime videos of each child/parent pair were coded based on the eating behavior coding system listed in Appendix B, according to which unit of behavior was the smallest meaningful action or utterance. The coding was done by an occupational therapist trained in identifying the behaviors of interest. A pilot coding was conducted on two different child/parent mealtime videos twice to check for the reliability of the coding. Each parent and child received scores of three behavioral categories reflecting the frequencies at which they exhibited behaviors in these categories.

Results. Table 1 lists the age and diagnosis of individual participants. All children had average or above-average intelligence. Regarding the Children's Mealtime Behavior Checklist, all of the children had at least 10 of the 19 eating behavioral problems, and their parents had at least six of the nine types of maladaptive behavior. We caution that since the results presented here are from a small, pilot user study, they do not provide conclusive evidence of the Racing Game Tray reducing poor eating behavior in young children. A much longer study with more subjects would be needed to show its effectiveness. However, we provide these results as they suggest that the Racing Game Tray affects eating behavior. Fig. 7 shows the mealtime duration of the four child/parent pairs both with and without the Racing Game Tray. Mealtime duration was measured by rounding up the time taken to complete the meal to the nearest minute. Before using the Racing Game Tray, the mealtimes for the four children (*A, B, C, D*) were (23, 40, 41, 25) minutes. Meanwhile, with the Racing Game Tray, their mealtimes were reduced to (23, 25, 29, 9) minutes. Except for child *A* whose meal time duration remained the same with the Racing Game Tray, children *B, C*, and *D* all exhibited improvements, reducing mealtime duration from 29% to 64%, suggesting that the Racing Game Tray may improve meal completion time. The lack of improvement in child *A* might be that her mealtime duration in our observation session was fine under 30 minutes without the Racing Game Tray, despite a complaint from her parent regarding long mealtime behavior.

Table 1. Results from the Children's Mealtime Behavior Checklist completed by parents

	Child			Parent	
	Gender	Age (Year)	Diagnosis	Relation	Age (Year)
A	Girl	7	Asperger's Syndrome	Mother	33
B	Boy	5	High function autism	Mother	43
C	Boy	5	Asperger's Syndrome	Mother	45
D	Boy	4	No specific diagnosis	Father	36

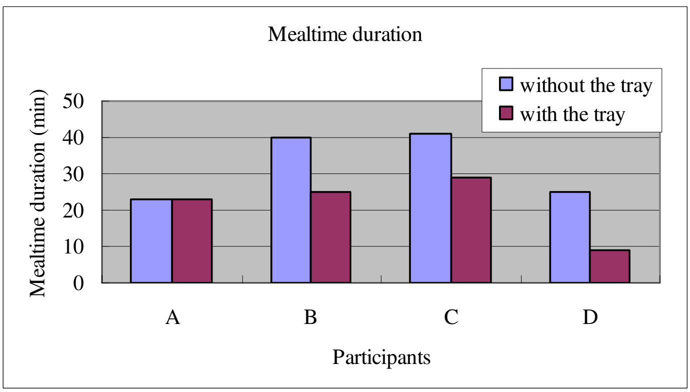
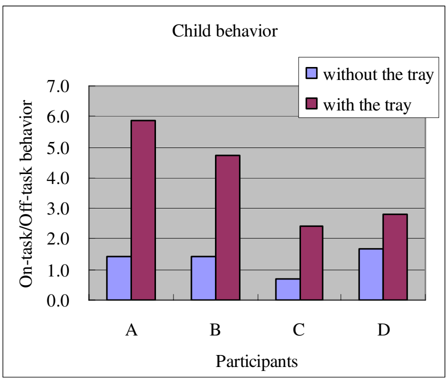


Fig. 7. Mealtime duration with and without the Racing Game Tray for the four children

Table 2 shows the results of mealtime interaction behavior between the four children and their parents with and without the use of the Racing Game Tray. By manually analyzing the recorded mealtime videos with and without the Racing Game Tray, this study identified positive, negative, and social behaviors of the parent and the child according to the definitions listed in Appendix B. For all parents and three children, the frequency of negative behavior decreased after using the Racing Game Tray; the frequency of negative behavior for child *D* was modest and showed only a slight increase from 3 to 8. The frequency of positive behavior for children either increased or didn't change much. However, for the parent's positive behavior in mealtime, the changes varied. Since the children were actively engaged in the eating activity when using the Racing Game Tray, their negative behaviors decreased. As a result, the necessity for the parents to promote self-feeding to their children might actually decrease. Regarding social behavior frequency, such behavior decreased for three of the

Table 2. The mealtime behavior with and without the Racing Game Tray

Pair	Location	Positive behavior		Negative behavior		Social behavior	
		Without tray	With tray	Without tray	With tray	Without tray	With tray
				Child's behavior			
A	Lab	52	88	18	6	19	9
B	Lab	80	76	37	4	19	12
C	Lab	40	79	50	5	6	28
D	Home	40	39	3	8	21	6
				Parent's behavior			
A	Lab	22	43	14	10	19	9
B	Lab	43	30	20	1	19	12
C	Lab	27	25	34	3	6	28
D	Home	8	10	2	0	14	6



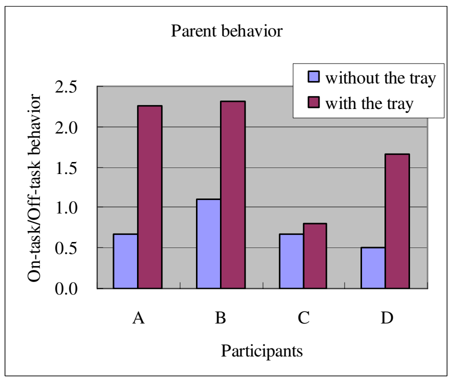


Fig. 8. On the left shows the child's on-task/off-task behavior ratio with and without the Racing Game Tray. On the right shows the parent's on-task/off-task behavior ratio with and without the Racing Game Tray. Positive behavior is on-task behavior, whereas both negative and social behaviors are off-task behavior. A high ratio of the on-task/off-task behavior is considered desirable, because it suggests greater frequency of on-task behavior versus off-task behavior.

child-parent pairs, and increased for one of the pairs. Since social behavior in this study is defined as behavior directed toward the feeding partner only but not directly related to feeding, such behavior can be a cause and/or effect of poor eating behavior.

Since the target task of this study is self-feeding, according to the definition listed in Appendix B, positive behavior is on-task behavior, while both negative and social behaviors is off-task behavior. A high ratio of the on-task/off-task behavior suggests greater frequency of on-task behavior versus off-task behavior. Results from Fig. 8 show that the ratios of on-task/off-task behavior improve for all children and parents. Without using the Racing Game Tray, child *C* had more off-task behavior than on-task behavior. For the other three children, about 40% of behavior is off-task. By using the Racing Game Tray, only 14~29% of behavior is off-task. These results suggest that by using the Racing Game Tray, children were more focused on self-feeding than without using the Racing Game Tray. In other words, the Racing Game Tray did not appear to distract them from self-feeding. In addition, Fig. 8 suggests that the parents also became more focused on the feeding task.

In summary, the preliminary results of using the Racing Game Tray designed based on the play-based occupational therapy model are encouraging. Due to the time constraint, we adopted a single-subject research design with four subjects. Each subject child used the Racing Game Tray only once. Continuing research is needed to investigate whether the effects of this study will be maintained when a child uses this Racing Game Tray repetitively until good eating behavior becomes a habit.

6 Related Work

King *et al.* [19] describe five persuasive strategies of adopting digital technology to change people's attitudes and behaviors. Specifically, these five strategies are simulated experiences, surveillance, environments of discovery, virtual groups, and personalizing. In the simulated experiences strategy, a simulated environment or object similar to its real part is created for a person to experience results of choosing different behavior. The surveillance strategy works by using monitoring and tracking to affect a person's behavior. The strategy of environments of discovery presents a fantasy environment where people's positive rewards can be given for their good behavior. The virtual group strategy leverages social competition and collaboration for persuasion. The personalizing strategy enhances the persuasiveness of information by tailoring it to individual users' interests or concerns. Fogg [4] introduces Captology, the study of computer-based persuasion. He presents a functional triad on how people view or respond to computers in three general ways, as tools, as media, and as social actors. Different functions suggest different types or designs for persuasive influence. He also maps out a total of 42 principles to design persuasive technologies. An example is called the Principle of Social Learning, which states that observing other people being rewarded for performing a certain behavior can serve as a good motivation. Some of these persuasive strategies and principles from King *et al.* [19] and Fogg [4] are adapted in the design presented here, including using digital media feedback as positive reinforcement for behavioral intervention. Additionally, this study emphasizes the playful aspect of the persuasive technology to maintain the interest of the children during the persuasion process.

There have been several case studies of persuasive technologies that target different behaviors with varying physical manifestations. We group these case studies under two general categories. The first category is focused on promoting physical activity in people's everyday life. Fish'n'Steps [2] is an interactive computer game to encourage physical activity. This game is based on a metaphor in which the act of growing a virtual fish in a tank symbolizes a similar act of caring for one's own body by walking a high step count. That is, the more players walk, the bigger their fishes grow in a virtual fish tank. By showing fishes from different players in the same virtual fish tank, this game adds the elements of social cooperation and competition among players. Houston [3] is a mobile phone application that encourages physical activity by sharing step counts and supportive comments among friends. Sharing of step counts and supportive comments provide social influence to persuade users to increase their daily step counts. The UbiFit Garden system [20] also wants to encourage physical activities. By using wearable sensors to detect and track people's physical activities, UbiFit displays their levels of exercises on a flower garden shown a cell phone. ViTo (as opposed to TiVo) [1] is a persuasive TV remote controller. This technology targets excessive TV watchers. By suggesting alternatives to TV watching, such as playing the Non-Exercise Activity Thermogenesis (NEAT) games (i.e., simple puzzles that use physical activity as their input), ViTo promotes reduced television viewing time.

The second category includes demonstrations of persuasive technology manifested into various everyday objects at home or in cars to motivate different behavioral change. These everyday objects are ideal for embedding persuasive technology because everyday activities naturally involve their use. The persuasive mirror [21] aims to motivate a lifestyle change by showing individuals what they may become in the future. If a person has poor lifestyle habits such as excessive eating, smoking, lack of exercise, *etc*., the mirror will conjecture an unpleasant future-face to persuade lifestyle change. Tooth Tunes [22] is a smart toothbrush designed to encourage better teeth-brushing in young children. The toothbrush is embedded with small pressure sensors to recognize brushing activity when the toothbrush is pressed against teeth. Upon the sensors being activated, a two-minute piece of music is played to reinforce children in continuing brushing for at least two minutes. Waterbot [23] is a persuasive device installed at a bathroom sink to track the amount of water usage in each wash. The system contains flow sensors to detect the amount of water usage. By showing the current water usage in comparison to the average household water usage, the system encourages behavioral change toward water conservation. Out [24] designed a high-tech doll that resembles a human baby to simulate the difficulty of caring for a baby. The target users are teenagers with the goal being to prevent teen pregnancy. The doll contains an embedded computer that triggers a crying sound at random intervals. To stop the crying, a caregiver must pay immediate attention to the doll by inserting a key into the back of the baby for a specific length of time to simulate a care session. CarCoach [25] is an educational car system that can utilize sensors in a car to detect good or bad driving habits, such as excessive braking, sudden acceleration, the use of signals when turning, *etc*. Subsequently, CarCoach aims to provide *polite*, proactive, and considerate feedback to drivers by factoring into their mental state and current road conditions.

Compared to the related work described above, the work presented here adopts a similar approach of embedding behavioral intervention into everyday objects. However, the approach proposed in this study also differs from that above. Most significantly, the proposed approach takes a play-based occupational therapy approach that uses persuasive technology to target young children, in which play-based persuasion provides the most effective means of solving child behavioral problems. In this work, we have found that persuasive, ubicomp technology is a good match for occupational therapy because occupational therapy emphasizes functional behavioral improvements that are often observable and measurable. Ubicomp technology can be deployed in patients' environments to detect their functional behaviors and provide just-in-time behavior modification intervention.

7 Conclusion and Future Work

In this paper, we have presented the Racing Game Tray, a playful tray that adopts Ubicomp and persuasive techniques into play-based occupational therapy for reducing poor eating behavior in young children after they reach their self-feeding age. Utilizing Ubicomp and persuasive technology extends the reach of occupational therapists from their treatment clinic into the actual living environment of a patient, enabling therapists to implement a direct intervention approach at the place where young children's eating behavior occurs and when the treatment is most effective. The design of the playful tray connects physical eating to digital playing activities to reinforce active participation of children in the activity of eating. Results of a pilot user study suggest that the Racing Game Tray may improve child meal completion time and reduce negative power play interactions between parents and children, resulting in an improved family mealtime experience.

An essential part of learning at home or in school for young children is about developing good habits, from brushing teeth properly in the morning to going to sleep on time at night. As shown in this study, children love to play and persuading behavior through games is effective for children. This study opens up many potential applications for adopting Ubicomp and persuasive techniques in play-based occupational therapy of young children.

Acknowledgement

We gratefully thank Sunny Consolvo for her tremendous effort on shepherding this paper.

References

1. Nawyn, J., Intille, S.S., Larson, K.: Embedding behavior modification strategies into a consumer electronic device: a case study. In: Proceedings of the 8th International Conference on Ubiquitous Computing, pp. 297–314 (2006)
2. Lin, J., Mamykina, L., Lindtner, S., Delajoux, G., Strub, H.: Fish'n'Steps: encouraging physical activity with an interactive computer game. In: Proceedings of the 8th International Conference on Ubiquitous Computing, pp. 261–278 (2006)
3. Consolvo, S., Everitt, K., Smith, I., Landay, J.A.: Design requirements for technologies that encourage physical activity. In: Proceedings of the SIGCHI Conference on Human Factors and Computing Systems, pp. 457–466 (2006)
4. Fogg, B.J.: Persuasive Technology: Using Computers to Change What We Think and Do. Morgan Kaufmann (2002)
5. Manikam, R., Perman, J.: Pediatric feeding disorders. Journal of Clinical Gastroenterology 30, 34–46 (2000)
6. Ha, P.B., Bentley, M.E., Pachon, H., Sripaipan, T., Caulfield, L.E., Marsh, D.R., Schroeder, D.G.: Caregiver styles of feeding and child acceptance of food in rural Viet Nam. Food and Nutrition Bulletin 23(4 Supplement), 95–100 (2002)
7. Hergenhahn, B.R.: An Introduction to Theories of Learning, 3rd edn. Prentice Hall, Englewood Cliffs, NJ (1988)

8. Bundy, A.C.: Play and playfulness: What to look for. In: Parham, L.D., Fazio, L.S. (eds.) Play in Occupational Therapy for Children, L, Mosby, MO (1997)
9. McMahon, R.J., Forehand, R.L.: Helping the noncompliant child—Family-based treatment for oppositional behavior, Guilford, NY, pp. 20–27 (2003)
10. Alessandrini, N.A.: Play—A child's world. Am. J. Occup. Ther. 3, 9–12 (1949)
11. Kielhofner, G.: A model of human occupational: Theory and application. Lippincott Williams & Wilkins, MD (2002)
12. Royeen, C.B., Duncan, M.: Acquisition frame of reference. In: Kramer, P., Hinojosa, J. (eds.) Frames of Reference for Pediatric Occupational Therapy, 2nd edn., pp. 377–400. Lippincott Williams & Wilkins, Wolters Kluwer Health (1999)
13. O'Brien, S., Repp, A.C., Williams, G.E., Christophersen, E.R.: Pediatric feeding disorders. Behavior Modification 15(3), 394–418 (1991)
14. Parham, L.D., Primeau, L.A.: Play and occupational therapy. In: Parham, L.D., Fazio, L.S. (eds.) Play in Occupational Therapy for Children, Mosby, MO (1997)
15. Lin, T.-Y., Chang, K.-H., Liu, S.-Y., Chu, H.-H.: A Persuasive Game to Encourage Healthy Dietary Behaviors of Young Children. In: Adjunct Proceedings of the 8th International Conference on Ubiquitous Computing (2006)
16. Crist, W., McDonnell, P., Beck, M., Gillespie, C., Barrett, P., Mathews, J.: Behavior at mealtimes and the young child with cystic fibrosis. Journal of Developmental and Behavioral Pediatrics 15(3), 157–161 (1994)
17. Wardle, J., Guthrie, C.A., Sanderson, S., Rapoport, L.: Development of the children's eating behaviour questionnaire. Journal of Child Psychology and Psychiatry and Allied Disciplines 42(7), 963–970 (2001)
18. Moore, A.C., Akhter, S., Aboud, F.E.: Responsive complementary feeding in rural Bangladesh. Social Science & Medicine 62(8), 1917–1930 (2006)
19. King, P., Tester, J.: The landscape of persuasive technologies. Communications of ACM 42(5), 31–38 (1999)
20. Consolvo, S., Paulos, E., Smith, I.: Mobile persuasion for everyday behavior change. In: Fogg, Eckles (ed.) Mobile Persuasion 20 Perspective on the Future of Behavior Change, Stanford Captology Media (2007)
21. Andrés del Valle, A.C., Opalach, A.: The persuasive mirror: computerized persuasion for healthy living. In: Proceedings of the 11th International Conference on Human-Computer Interaction (2005)
22. Hasbro, Inc., TOOTH TUNES, http://www.hasbro.com/toothtunes/
23. Arroyo, E., Bonanni, L., Selker, T.: Waterbot: exploring feedback and persuasive techniques at the sink. In: Proceedings of Conference on Human Factors in Computing Systems, pp. 631–639 (2005)
24. Out, J.W.: Baby Think It Over: Using role-play to prevent teen pregnancy. Adolescence 36(143), 571–582 (2001)
25. Arroyo, E., Sullivan, S., Selker, T.: CarCoach: a polite and effective driving coach. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 357–362 (2006)

Appendix A: Children's Mealtime Behavior Checklist

Child's Name:				Date:	
Filled by:				Relation to the child:	
Child Behavior					**Descriptions**
My child eats	less	more	the same	when s/he is upset.	
My child eats	less	more	the same	when s/he is angry.	
My child eats	less	more	the same	when s/he is tired.	
My child eats	less	more	the same	when s/he is happy.	
My child eats	less	more	the same	when s/he is anxious.	
My child eats	less	more	the same	when s/he is annoyed.	
My child eats	less	more	the same	when s/he is worried.	
My child eats	less	more	the same	when s/he has nothing to do.	

Please check all boxes that apply	**Descriptions**
□ My child chokes at mealtime.	
□ My child eats only ground or soft food.	
□ My child refuses to eat meals but requests food immediately after meal.	
□ My child has trouble tasting new foods.	
□ My child gags or vomits at mealtime.	When? How often?
□ My child is a picky eater.	Likes or dislikes what?
□ My child gets up from table during a meal.	
□ My child keeps food in his/her mouth without swallowing it.	
□ My child Spits out food during a meal.	
□ My child plays with food, such as eating rice one grain at a time, or noodles one string at a time.	
□ My child stops eating by talking or singing during a meal.	
□ My child stops eating or chewing while doing nothing.	
□ My child attempts to negotiate what he/she will and will not eat.	
□ My child always leaves leftover or requires other people to feed him/her.	
□ My child would rather drink milk than eat meals.	
□ My child likes to eat snack foods.	Type? Time? Frequency?
□ My child always asks for a drink.	
□ My child eats slowly.	
□ My child eats more and more slowly during the course of a meal.	

Parent Behavior	**Descriptions**
□ I get anxious and/or frustrated when feeding my child.	
□ I coax my child to get him/her to take a bite.	
□ I use threats to get my child to eat.	
□ I feel worried my child doesn't get enough to eat.	
□ If child doesn't like what is served, I make something else.	
□ I feel that there is no way for me to get my child to eat in a well-behaved manner.	
□ When my child refuses food, I force food into his/her mouth.	
□ Getting my child to eat often makes me very angry.	
□ I will feed my child if he/she doesn't eat himself/herself.	

Appendix B: Behavioral Feeding Codes for Children

<table>
<tr><td colspan="2">(1) Self-feeding: a child place food into his/her own mouth</td></tr>
<tr><th>Parent</th><th>Child</th></tr>
<tr><td>Positive: A parent allows or promotes self-feeding, such as verbal encouragement, praises, etc.</td><td>Positive: A child attempts self-feeding, such as holding utensils, putting food into mouth, etc.</td></tr>
<tr><td>Negative: A parent discourages, disallows, or interrupts self-feeding, such as pushing the child's hands away, telling the child that she will feed the child, etc.</td><td>Negative: A child rejects self-feeding, such as saying "no" or pushing away given food.</td></tr>
<tr><td colspan="2">(2) Interaction: Actively initiated behavior and the synchronous responsive behavior of the feeding partner</td></tr>
<tr><th>Parent as the actor</th><th>Child's responsive behavior</th></tr>
<tr><td rowspan="2">Positive: A parent attempts to arouse a child's interest, such as talking about food, models, food games, etc. A parent refocuses the child's attention on food when the child is distracted.</td><td>Positive: A child accepts food when it is offered, or self-feeds food.</td></tr>
<tr><td>Negative: A child ignores the parent's cue, refuses, or walks away from the parent's cue.</td></tr>
<tr><td rowspan="2">Negative: A parent intrusively attempts to direct feeding, such as force-feeding the child, holding a child's head, body, or hand, and threatening the child.</td><td>Positive: A child responds by self-feeding.</td></tr>
<tr><td>Negative: A child ignores the parent's attempts, refuses, or walks away from the parent's attempts.</td></tr>
<tr><th>Parent's responsive behavior</th><th>Child as the actor</th></tr>
<tr><td>Positive: A parent synchronously responds to promote continuous feeding, such as interpreting a child feeding cues, responding to a child's needs, etc.</td><td rowspan="2">Positive: A child initiates an attempt to eat, such as looking at food, talking about food, requesting food/drink, or touching food.</td></tr>
<tr><td>Negative: A parent synchronously responds to interrupt the child's feeding.</td></tr>
<tr><td>Positive: A parent synchronously responds to promote continuous feeding, such as interpreting the child feeding cues, responding to the child's needs, etc.</td><td rowspan="2">Negative: A child shows disinterest, discouragement, or stops eating or chewing.</td></tr>
<tr><td>Negative: A parent synchronously responds to interrupt the child's feeding.</td></tr>
<tr><td colspan="2">(3) Social behavior: Toward feeding partner only but not directly related to feeding</td></tr>
<tr><td>Behavior such as talking, touching, smiling, looking, laughing, etc.</td><td>Behavior such as talking, touching, smiling, looking, laughing, whining, or crying.</td></tr>
<tr><td colspan="2">(4) Others</td></tr>
<tr><td>The parent feeds the child directly without any special responsive or encouraging strategy.</td><td>A child stops or refuses to eat without any evidence of environmental distracters.</td></tr>
</table>