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遊戲中改善幼兒用餐行爲-
結合職能治療、普及計算與說服力科技的好玩餐盤

Playful Tray: Adopting Ubicomp and Persuasive Techniques into Play-based Occupational Therapy for Correcting Poor Eating Behaviors in Young Children

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Abstract

This study has created a playful tray that adopts Ubicomp and persuasive techniques into play-based occupational therapy for correcting eating problems in young children after they reached their self-feeding age. The design of the playful tray integrates eating activity and digital play to reinforce active participation of children in eating activity. User study results have shown that using the playful tray can effectively improve child meal completion time by 35%. More significantly, user study results have demonstrated that the playful tray also markedly reduces negative power play interaction between mothers and children by an average of 58%, and significantly improves family mealtime experience.

摘要

論文中實做了結合職能治療、普及計算與說服力科技的好玩餐盤，期能藉此改善幼兒的用餐問題。好玩餐盤的設計在於把吃飯的行為跟數位遊戲做緊密的連結，以正向回饋強化幼兒用餐時的參與感。實驗結果發現，好玩餐盤能有效縮短幼兒的用餐時間達 35%；並且值得注意的是，好玩餐盤更顯著地降低了親子間負面的權利關係，使負面行為數量的改善達到 58%。

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Chapter 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 behaviors, 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 patient, enabling the therapists to utilize Ubicomp technology to implement an effective behavior intervention program at the place where the patient'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. 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 [5]. For example, poor eating habits at home by children can cause stressful confrontations with parents, often taking the form of a *power play* involving mental persistence and pitting parental persuasion against unrelenting re-

fusal 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, shown in Figure 1.1, has designed and implemented a *playful tray* as a tool to assist occupational therapists in correcting poor eating behavior in young children. This tool can be used either at home or in school. Experimental studies on autistic and non-autistic children with mealtime problems demonstrated that the playful tray can *significantly improve* mealtime performance compared to traditional parental verbal persuasion. More importantly, based on analysis of parent-children interactions where the playful tray is used, the playful tray markedly *reduces negative power play interactions* between children and parents during mealtimes; i.e., the negative active and responsive behaviors by a mother and her child. The playful tray not only helps solve eating problems involving children, but also improves the quality of parent-child mealtime interactions and the family mealtime experience.

Figure 1.1 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 mother will become angry with her. Her mother's angry voice will also wipe out her appetite. On the right, this young child is actively eating to play the racing game against her mother.

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. Engaging children in this fun interactive game motivates the children to change their eating behavior. Using the *natural* eating actions of children as inputs to the game is *critical* because eating is the target physical activity. Once children become attracted to the playful digital game, they find that they must eat to continue playing. This design successfully and seamlessly connects and integrates *the fun part (coming from the digital game activity) with the physical activity of eating.* We believe that this is the main reason why the playful tray effectively corrects child eating behavior.

The tray design is based on learning theories and the key components of *playfulness* [6], [7]. The design integrates eating activity and play to *reinforce the active participation of children in eating activity*, thus making mealtimes unproblematic 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 [8]. 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. However, this approach is time and energy consuming. Furthermore, the traditional method may also be ineffective because of non-compliance from parents, who often let emotions get in the way in real parent-child confrontations. This study thus sought to create the playful tray. This study hypothesizes that linking physical eating with a digital game can enhance child motivation to eat, increase eating speed, decrease maladaptive

behaviors, and reduce negative parental active or responsive behaviors. The result will be higher quality family mealtime experiences for both parent and child. User study results involving the use of the tray by young children with eating problems have validated these hypotheses, with child eating behavior demonstrating a significant improvement.

This study makes the following two contributions.

- This study created a working playful tray and tested it on four young children (two with asperger's syndrome, one with high function autism, and one with no specific diagnosis) aged from 4 to 7 years old with eating problems. The user study results have shown that using the playful tray can effectively improve child mealtime performance by reducing average meal completion time by 35%. In addition, the user study results have shown that the playful tray also markedly reduces negative power play interaction between mothers and children by an average of 58%, and significantly improves family mealtime quality.
- This study successfully integrated play-based occupation therapy into persuasive technology. By embedding persuasive technology into an everyday object in which the target behavior involves its use, effective behavioral improvement can be achieved.

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 the related work. Finally, Section 7 presents conclusions and future research directions.

Chapter 2

Related Work

"Although computers have not introduced new strategies of persuasion, they have allowed people to implement old strategies in new ways." [9] King *et al.* describe five persuasive strategies that adopt digital technology to change people's attitudes and behaviors; the five strategies are simulated experiences, surveillance, environments of discovery, virtual groups, and personalizing. One of the main strategies that the playful tray applies is to create "environments of discovery," which contains three chief components: providing a fantasy environment for users; giving them control over much of the environment; and giving them positive feedbacks for performing target activities. Meanwhile, 5-A-Day Adventures [10], which encourages children to eat certain fruits and vegetables by animated characters, music and games, also includes the "environments of discovery" as a main persuasive strategy. Yet, as front, the playful tray adopts and implements the strategy in a quite distinct way from other applications. While 5-A-Day Adventures provides rich feedbacks in the environment as persuasive factors, our work tends to use sensors and animated games in the environment to turn the target behavior itself into a persuasive play.

Besides, Fogg [4] listed basic principles for designing persuasive technology. Some of these principles are also 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 demonstrations of persuasive technology embedded into various everyday objects. These everyday objects are ideal for embedding persuasive technology because everyday activities naturally involve their use. ViTo (as opposed to TiVo) [1] is a persuasive TV remote controller. This technology targets couch potatoes watching excessive amount of television. By suggesting alternatives to TV watching, ViTo promotes reduced television viewing time. The persuasive mirror [11] 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 changed lifestyle habits. TOOTH TUNES [12] 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 the brushing for at least two minutes. CarCoach [13] 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. Waterbot [14] 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. Fish'n'Steps [2] is an interactive computer game to encourage physical activity. The game links the number of players' step counts with the sizes

of their fishes – the more they walk, the bigger their fishes grow in a virtual pond. The UbiFit [3] project 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. Out [15] designed a high-tech doll that resembles the 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 and holding it in place.

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 on functional behavioral improvement that are often observable and measurable. Ubicomp technology can be deployed in the environments of the patients to detect their functional behaviors and provide just-in-time behavior modification intervention.

Chapter 3

Play-based Feeding Behavior Intervention

"Play is a child's way of learning and an outlet for his innate need of activity." [16] 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, a child 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. That is, a more direct approach is to make the target functional activity playful to engage the child into active participation.

According to theories of play and playfulness [7], 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. That is, it is the activity itself rather than its consequences that attract participant active participation. Moreover, internal control is defined as individuals being in charge of *their* actions and at least some aspects of the activity outcome. Freedom to suspend reality refers to the pretend quality of play.

On the other hand, acquisitional theory views behavior as a response to an environment [17]. The environment thus either reinforces behaviors or fails to provide positive reinforcement by instead giving no reinforcement at all. Positive reinforcement strengthens behaviors by rewarding the desired behavioral response. Previous studies have shown [6] that partial reinforcement is the strongest form of reinforcement in shaping behaviors. 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.

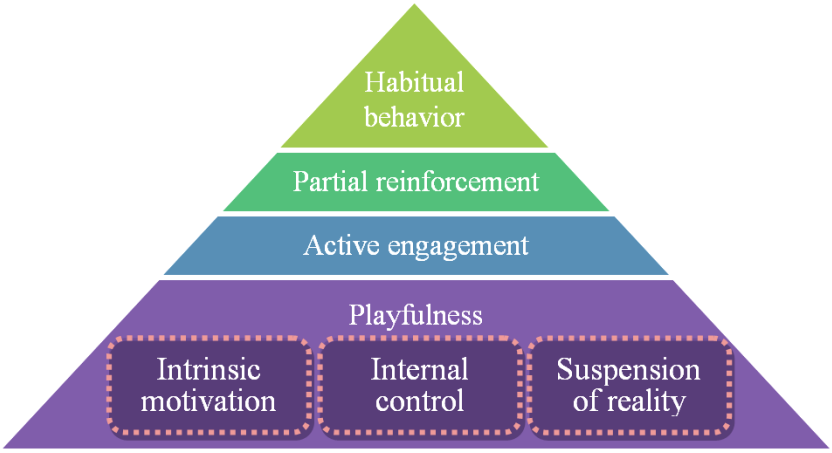

Figure 3.1 Schematic representation of the play-based occupational therapy model.

Combining the model of playfulness and the principles of reinforcement, this study developed a play-based occupational therapy model for designing the playful tray. In this model, shown in Figure 3.1, the three elements of playfulness

comprise the foundation of activity design. To successfully induce active child participation in an activity, activity designs should provide an elevated degree of intrinsic motivation (less extrinsic motivation), internal control (less external control), and freedom of suspension of reality. Furthermore, the design should employ the principle of partial reinforcement, embedded in an activity, to strengthen desirable behaviors through repetition. Using partial reinforcement reinforce the behavior of active engagement so that it can be internalized and become a habit. This approach can successfully develop good habits.

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 [18]. 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, 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. By using the playful tray at mealtimes, children are motivated to improve their eating pace, and maladaptive behaviors are reduced.

Chapter 4

Playful Tray Design Considerations

Based on the play-based occupational therapy model described above, this study 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 bring intrinsic motivation of children, (3) *engagement* to connect digital playfulness to active participation in the target physical activity, 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 physical eating activity. Because the use of the digital game is intended to motivate active child participation in the physical eating activity, the digital game design should not draw too much attention away from the physical eating activity and thus lead to the undesirable result of digital playing overtaking or distracting physical eating. That is, a game design should bring in just enough digital interactivity to maintain the interest of children in the physical 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. Enjoyment from game playing can generally be classified into two types – *external stimulus* and *self-accomplishment*. External stimulus is defined as enjoyment responses deriving from environmental stimulus, for example: perception arousal from watching entertaining animation. Meanwhile, self-accomplishment describes the enjoyment derived from overcoming a challenge, for example solving a puzzle. The enjoyment comes from the sense of achievement by succeeding in a challenging activity, further reinforcing engagement. The difference is that this type of enjoyment is self-reinforced rather than reinforced by external stimulation. Therapists thus generally prefer self-accomplishment to external stimulus. This study used a game design based on self-accomplishment.

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 study successfully 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 proposed game design allows children to determine their eating pace.

Two further design considerations are presented below:

- It is important to minimize the change on the lunch-ware 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 attract and maintain their attention.

Chapter 5

Playful Tray Design and Implementation

Two prototypes of playful trays were created. Figure 5.1 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.

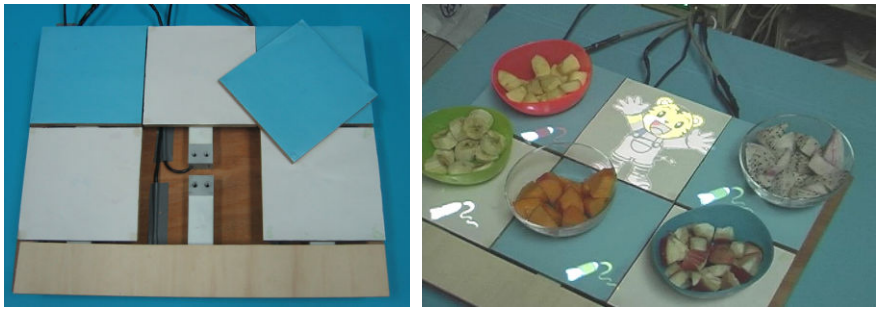

Figure 5.1 Initial playful tray prototype called the “coloring game”.

A preliminary user study on young children identified four problems in 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 were simpler, it was also more effective than the initial prototype.

5.1 Single-cell Tray

The racing game tray prototype is shown in Figure 5.2. 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.

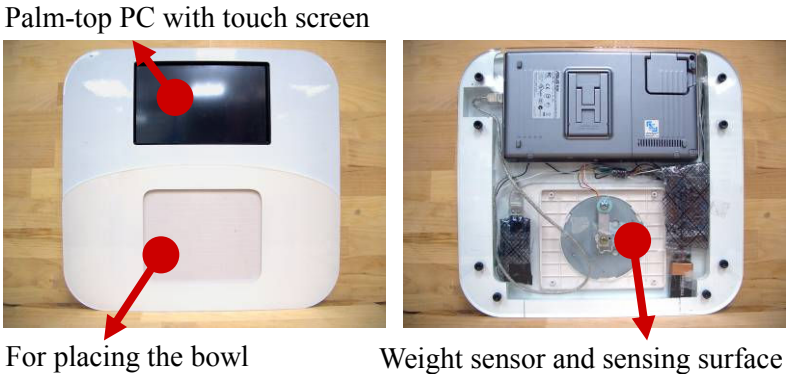

Figure 5.2 The revised playful tray prototype, called the "racing game".

The system architecture is shown in Figure 5.3. 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. Since young children can exhibit a wide variety of eating and non-eating behaviors during meal times, 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 tough hit 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 a child may first press their hands into the bowl, creating a weigh 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 behavior.

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

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

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, 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 in the *racing game* described below.

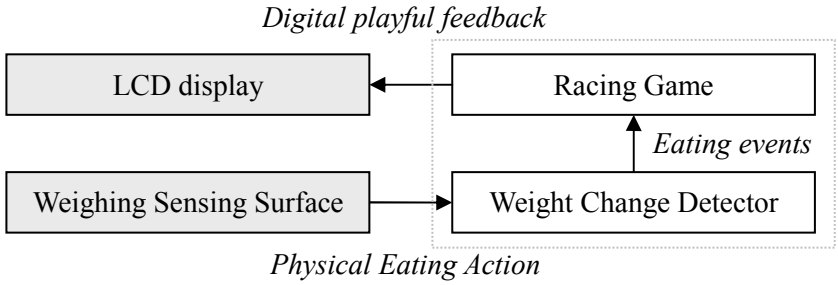

Figure 5.3 System architecture.

5.2 The Racing Game

Screenshots for the racing game are shown in Figure 5.4. When starting a meal, a child selects a favorite cartoon character, as illustrated in the left screenshot of Figure 5.4. The child's mother can also participate in the race by selecting a second character, after which the race begins. Upon detecting each eating action, a *randomly selected* character races one step forward to the right. The distance traveled is fixed regardless of the size of the weight change from each eating action. The right screenshot in Figure 5.4 shows the state of a race after a number of eating actions. When a 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 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.

Figure 5.4 Screen shots for the racing game played on the LCD of the playful tray.

The racing game design strategies follow the play-based occupational therapy model described in Section 2. The enjoyment, as an intrinsic motivation for this game, derives from self-accomplishment. That is, through eating, children help their character to win the race. This game provides intrinsic control to children, allowing them to choose a favorite cartoon character to compete in the race. The pace of the game is moderate compared to video games, diverting only a moderate portion of the child's attention away from eating. This game follows our engagement criteria by using the natural eating actions of children as game inputs. Finally, the game adopts the partial reinforcement approach by randomly selecting a character to move forward.

Chapter 6

User Studies and Results

User studies are based on a single-subject design. Although return to the baseline is essential in single-subject designs to demonstrate that a treatment method is responsible for behavioral change, since the objective of user studies is to assess the effectiveness of playful tray in correcting child eating behavior, and since the effectiveness is accumulative, it is impossible to return to the baseline situation. Instead, an identical procedure was replicated across four different subjects who exhibited similar mealtime problems. The replication of treatment effectiveness across different subjects demonstrates that the effects of behavioral changes are result from the treatment [19].

6.1 Participants

The participants comprised four children aged from 4 to 7 years old. The participants are referred to here as subjects *A, B, C*, and *D*. Subjects *A* and *B* were diagnosed with Asperger's syndrome, subject *C* had high function autism, and subject *D* had no specific diagnosis. The common complaint regarding mealtimes for all subjects was long meals, ranging from over 30 minutes to over one hour, after the children reached the age of self-feeding.

6.2 Procedure and Measures

An occupational therapist first administered a semi-structured interview. A parent-report, Children's Mealtime Behavior Checklist (shown in Table 6.2), was filled out and followed by an interview to clarify behavioral details. This checklist, including 18 child behaviors and nine parent behaviors, was modified from the Behavioral Pediatrics Feeding Assessment Scale [20] and the Children's Eating Behavior Questionnaire [21]. After receiving informed consent, the child and mother/caregiver were first: (1) invited to take their meals at our clinic or an investigator was dispatched to the home of the child during their mealtime to record their eating activities before using the playful tray, then (2) another mealtime appointment was made within one week to record their eating activities using the playful tray. The mealtime episodes were videotaped via video camera set in the same room. After setting up the video camera and/or playful tray, the mother/caregiver 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 playful tray.

An eating behavior coding system, as listed in Table 6.1, was modified from the system created by Moore *et al.* [22]. The coding system consists of three behavioral categories: *active feeding*, *interaction*, and *social behavior*. 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, behaviors were classified as either positive or negative: positive behavior describes behaviors associated with promotion of self-feeding, whereas negative behavior describes behaviors associated with aver-

sion, intrusion, or interruption of self-feeding. The codes are mutually exclusive. Table 6.1 lists the details of the codes together with behavioral examples.

Based on analysis of mealtime videos, the behaviors of both mother and child were coded, according to which unit of behavior was the smallest meaningful action or utterance. The interaction category included coding of both active and responsive behaviors. Each mother and child received a behavioral category score reflecting the frequency with which they exhibited behaviors in that category.

Table 6.1 Behavioral Feeding Codes for Children

(1) Self-feeding: a child place food into his/her own mouth	
Mother	**Child**
Positive: A mother allows or promotes self-feeding, such as verbal encouragement, praises, etc.	Positive: A child attempts self-feeding, such as holding utensils, putting food into mouth, etc.
Negative: A mother discourages, disallows, or interrupts self-feeding, such as pushing the child's hands away, telling the child that she will feed the child, etc.	Negative: A child rejects self-feeding, such as saying "no" or pushing away given food.
(2) Interaction: Actively initiated behavior and the synchronous responsive behavior of the feeding partner	
Mother as the actor	**Child's responsive behavior**
Positive: A mother attempts to arouse a child's interest, such as talking about food, models, food	Positive: A child accepts food when it is offered, or self-feeds food.

<table>
<tr><td>games, etc. A mother refocuses the child's attention on food when the child is distracted.</td><td>Negative: A child ignores the mother's cue, refuses, or walks away from the mother's cue.</td></tr>
<tr><td rowspan="2">Negative: A mother 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 mother's attempts, refuses, or walks away from the mother's attempts.</td></tr>
<tr><td>Mother's responsive behavior</td><td>Child as the actor</td></tr>
<tr><td>Positive: A mother 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 mother synchronously responds to interrupt the child's feeding.</td></tr>
<tr><td>Positive: A mother 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 mother 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>
</table>

(4) Others	
The mother feeds the child directly without any special responsive or encouraging strategy.	A child stops or refuses to eat without any evidence of environmental distracters.

Table 6.2 Children's Mealtime Behavior Checklist

Child's Name:	Date:
Filled by:	Relation to the child:

Child Behaviors	**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.	

Mother 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.	

6.3 Results

Table 6.3 lists the age and diagnosis of individual subjects. 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 18 eating behavioral problems, and their mothers had at least six of the nine maladaptive behaviors. Figure 6.1 shows the mealtime duration of the four subjects both with and without the playful tray. Mealtime duration is measured by rounding up the time taken to complete the meal to the nearest minute. Before using the playful tray, the average mealtime duration for the four children was 32 minutes (with a range of between 23 and 41 minutes). Meanwhile, with the playful tray, the average mealtime duration reduced to 21 minutes (with a range of between 7 and 29 minutes), representing a significant reduction of 35% or 11 minutes. Except for subject *A* whose meal time duration did not improve with the playful tray, children *A, B*, and *C* all exhibited significant improvements, reducing mealtime duration from 29% to 72%.

Table 6.3 Results from the Children's Mealtime Behavior Checklist filled by mothers.

			Maladaptive Behaviors	
Child	Age	Diagnosis	Child	Mother
A	7-10	Asperger's Syndrome	10	6
B	5-9	High function autism	10	8
C	5-0	Asperger's Syndrome	11	6
D	4-10	No specific diagnosis	12	8

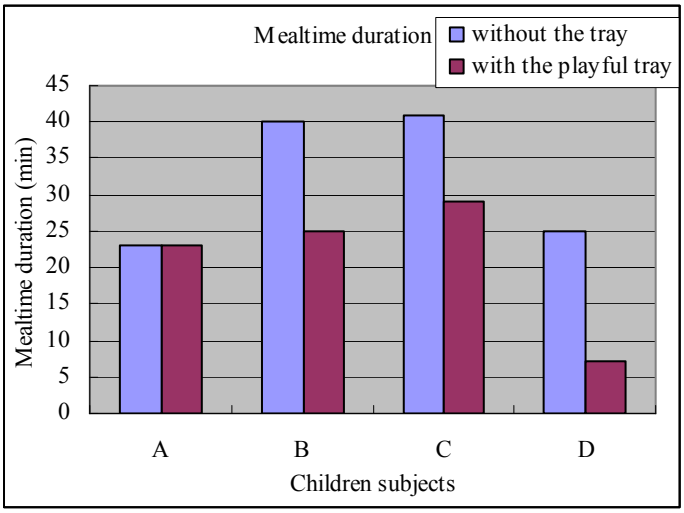

Figure 6.1 Mealtime duration with and without the playful tray for the four children subjects.

Table 6.4 Mealtime behavior with and without the playful tray.

Child	Child's behavior				Mother's behavior			
	No tray		With tray		Without tray		With tray	
	P/N	Social	P/N	Social	P/N	Social	P/N	Social
A	2.89	19	14.67	9	1.57	19	4.30	9
B	2.16	19	19.00	12	2.15	19	30.00	12
C	0.80	6	15.80	28	0.79	6	8.33	28
D	13.33	21	6.75	11	4.00	14	9.00	11

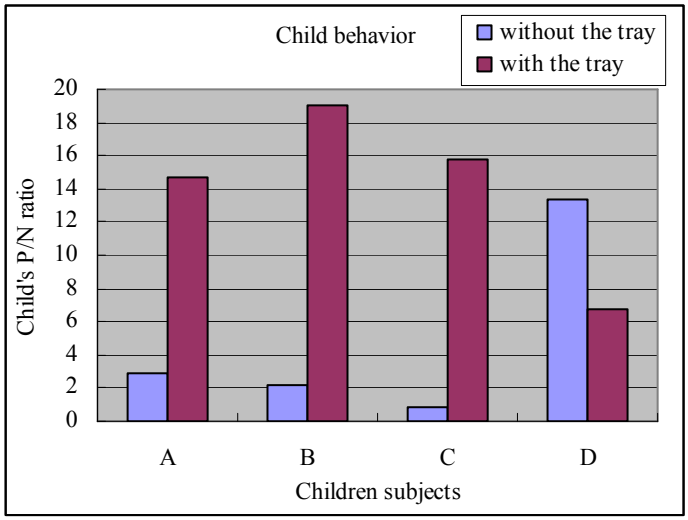

Figure 6.2 The child's P/N ratio (number of positive over negative behavior from the child) with and without the playful tray.

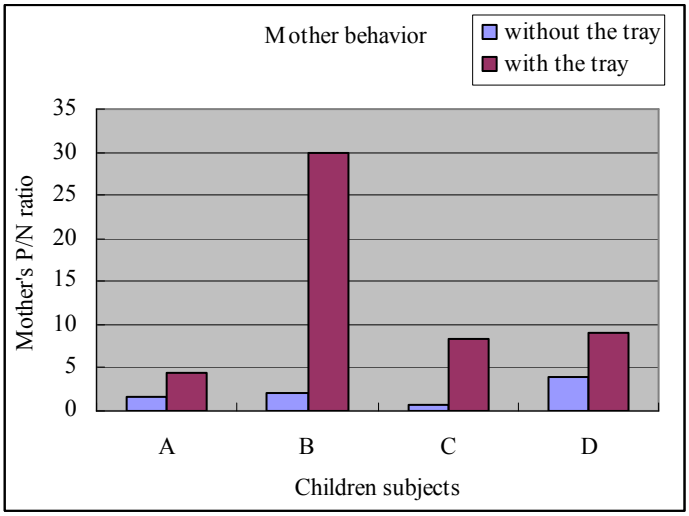

Figure 6.3 The mother's P/N ratio (number of positive over negative behavior from the mother) with and without the playful tray.

Table 6.4, Figure 6.2 and Figure 6.3 show the results of mealtime interaction behavior between the four children subjects and their mothers with and without the use of the playful tray. By manually analyzing the recorded mealtime videos

with and without the playful tray, this study identified positive (*P*) and negative (*N*) behavior of the mother and the child according to the definition listed in Table 6.1. The P/N ratios for the behavior of the mother and child were then calculated. The P/N ratio was used to measure behavioral improvement between meal eating without and with the playful tray. High P/N ratio indicates greater frequency of positive behavior versus negative behavior. Before using the playful tray, the P/N ratio range of the child behavior was [0.80 ~ 13.33], whereas that of the mother behavior was [0.79 ~ 4]. With the playful tray, the P/N ratio of the child behavior improved to [6.75 ~ 19], while that of the mother improved to [4.30 ~ 30]. Other than child *D*, all three children and their mothers exhibited significant behavioral improvement as shown by increasing P/N ratio. Consequently, when the children use the playful tray, the frequency of negative behavior versus positive behavior decreases for *both mothers and children*.

The following provides some explanations for the lack of improvement in child subject *D*. We believe that the lack of improvement resulted primarily from differences in the types of food served in the meal with and without the playful tray. In the first meal without the playful tray, the served food was white rice mixed with vegetables and meat, while the meal with the playful tray comprised dumplings. Since dumplings are easier and more efficient to eat for a child (requiring only one or two bites per piece) than rice with vegetables and meats (which the child must scoop up with a spoon), there were fewer instances of active self-feeding actions in the second meal (16) than the first meal (25). Additionally, since the number of negative behaviors from subject *D* was small (3 in the first meal and 4 in the second meal), the P/N ratio was also small.

Regarding social behavior frequency, such behaviors decreased for three of the child-mother couples, and increased for one of the couples. Since social behavior in this study is defined as behaviors directed toward the feeding partner only but not directly related to feeding, such behaviors can be a cause and/or effect of

poor eating behavior. On the other hand, mealtimes can be considered a social interaction arena. For example, consider the couple (child *C*) who exhibited more social behavior while using the playful lunch tray to eat. Rather than displaying increasing feeding problems, both meal duration and negative behaviors reduced markedly. The interpretation of social behavior during mealtimes thus must be considered cautiously.

Chapter 7

Conclusion and Future Work

This study has created a playful tray that adopts Ubicomp and persuasive techniques into play-based occupational therapy for correcting eating problems in young children after they reached 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 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 eating activity. User study results have shown that using the playful tray can effectively improve child meal completion time by 35%. More significantly, user study results have demonstrated that the playful tray also markedly reduces negative power play interaction between mothers and children by an average of 58%, and significantly improves family mealtime experience.

This study opens up many potential applications for adopting Ubicomp and persuasive techniques in play-based occupational therapy of young children. An essential part of learning at home or schools 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 beha-

vior through games is effective for children. In addition, games can carry a rich amount of implicit information. This characteristic of games make them easy to integrate digital technology into everyday life, especially for young children who are unfamiliar with using computers.

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