ExciteTray: Developing an Assistive Technology to Promote Self-Feeding Among Young Children

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ABSTRACT

Typically developing children usually master self-feeding by the age of three years. However, children with Cerebral Palsy and other developmental disabilities encounter great difficulties acquiring this instrumental ability. In an effort to motivate young eaters in the process of acquiring self-feeding abilities, we set out to develop ExciteTray – a customized self-feeding assistive technology. We describe the initial stages of an iterative design process consisting of interviews with domain experts, rapid-prototyping, and evaluations with children. Based on our findings, we formulated preliminary design principles for a self-feeding assistive technology: draw attention without causing distraction; motivate the child during the various stages of self-feeding; facilitate face-to-face interaction between caregiver and child; adapt feedback to the cognitive and motor ability of each child. We explain how these principles were implemented in a prototype, discuss safety considerations and describe future work.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Prototyping, User-centered design.* K.4.2 [**Computers and Society**]: Social Issues – *Assistive technologies for persons with disabilities.*

General Terms

Design, Human Factors.

Keywords

Food; Self-Feeding; Children; Caregiver; Assistive Technology; Cerebral Palsy.

1. INTRODUCTION

Eating is a complex process with physiological, biomechanical, and behavioral aspects involving the whole body [12]. Food items must be identified and located, grasped to be brought to the mouth, ingested, chewed, swallowed and digested. Disruption of any one of these steps may lead to malnutrition, poor growth, developmental delay and loss of general health and well-being. Eating and feeding are also emotional and social experiences for both caregiver and child, with opportunities for communication and intimacy but which may also entail struggle and conflict [1].

Self-feeding involves a complex, multi-dimensional process with sub-systems that are expected to dynamically self-organize as children shift to higher levels of independent performance [15]. The self-feeding process is mastered by a typically developing child by the age of three years [7, 12, 14]. In contrast, children with Cerebral Palsy (CP) and other developmental disabilities have great difficulty in becoming independent in this vital skill.

CP describes a group of developmental disorders of movement and posture leading to activity restriction that is attributed to disturbances occurring in the fetal or infant brain [13]. Motor impairment may be accompanied by a seizure disorder and by disturbances of sensation, cognition, communication and behavior [2]. Children with CP often have significant feeding and eating difficulties due to impairments in oral-motor control, posture and movement [4] or their difficulty in consuming different textures of food [16].

We set out to develop a customized self-feeding assistive technology, aimed to motivate very young children with CP throughout the gradual process of acquiring independent eating skills. The technology – ExciteTray – is currently in its second prototype stage. The iterative design and prototyping process consists of interviews with domain experts, rapid-prototyping, and evaluations of children while they eat with the tray. In this paper we describe the design principles formulated thus far, present our initial prototypes and discuss findings from a user study.

2. RELATED WORK

Food-related interactions have been recognized as a challenge for the HCI community, because physical, physiological, cognitive and social factors have to be taken into account [5]. It is particularly challenging to design such interactions for young children due to developmental and safety concerns.

EducaTableware [10] are interactive tableware devices (fork or cup) intended to make eating more enjoyable by emitting sounds when a child eats or drinks. Sensing Fork [8, 9] is a fork-type sensing device, which detects children's eating actions and chosen food items. This device is connected to a smartphone that analyzes sensor data, and provides feedback through a game application. Playful Bottle [3] is an augmented water bottle that uses a smartphone to track water intake. It aims to encourage drinking by using water intake as input for a mobile game. Playful Tray [11] aims to reduce meal completion time with a weight-

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sensitive tray that tracks children's eating actions. These are then used as input for an interactive game embedded within the tray.

While these systems address various challenges experienced by children while eating and drinking, they have not been adapted to the unique requirements of children with developmental disabilities such as CP. Furthermore, many systems draw attention to a screen-based game, thereby reducing face-to-face interaction between caregiver and child during meals. In contrast, we strive to develop a system that preserves face-to-face interactions rather than shift the child's or caregiver's attention towards a screen.

3. SYSTEM DESIGN PROCESS

ExciteTray is being designed by an interdisciplinary team that includes an occupational therapist specializing in CP management, a rehabilitation technology researcher, and HCI researchers and practitioners. We set out to develop an assistive technology that motivates young children in the process of acquiring self-feeding skills.

3.1 Interviews with Domain Experts

Our first step was interviewing expert clinicians who treat children with developmental disabilities.

3.1.1 Participants

Participants were staff members of a rehabilitation daycare center for young children (8-36 months old): the director of the center, a senior care-giver, an occupational therapist, and an assistant. All participants feed children with developmental disabilities, including CP, on a daily basis.

3.1.2 Method

Interviews were conducted at the daycare center while participants were not actively caring for the children. Participants were interviewed separately, for approximately 20 minutes each, regarding the challenges they face in feeding children, and types of feedback they give during meals. The interviews were recorded with the consent of participants. The recordings were later transcribed and independently analyzed by two researchers to identify emerging common themes.

3.1.3 Results and Discussion

Participants described a typical meal at the daycare center as a shared experience, where all children sit at a communal table and eat their meal at the same time. Each staff member is in charge of 1 or 2 children. Children with developmental disabilities have difficulty in focusing only on eating, so staff members often need to draw their attention to the plate, and verbally motivate them throughout the meal. Considering that children have a wide range of motor and cognitive impairments, caregivers must adapt "verbal rewards" according to the individual needs of each child. It was agreed by all participants that the most common challenge in the self-feeding process is using a utensil to scoop food from the plate.

In addition, it was evident that the act of feeding has considerable implications beyond nutrition; this daily interaction with caregivers is an intimate, bonding experience that provides social and emotional support for the children. This daily interaction also enables caregivers to monitor individual progress.

Based on these findings, we formulated five preliminary design principles for a self-feeding assistive technology: (1) Draw attention to the plate. (2) Motivate the child during the various stages of self-feeding. (3) Avoid or prevent distractions, to the child and to others. (4) Facilitate face-to-face interaction between caregiver and child. (5) Adapt feedback to the individual cognitive and motor ability of each child.

3.2 Initial Prototype

The first iteration of the prototype consisted of a standard food tray that was augmented with 10 LEDs, mounted in a row just below the surface near its upper edge (see Figure 1, left). The LEDs were programmed to display animations including blinking and side-to-side wave. The lights are intended to draw the child's attention towards the plate (design principle 1), and act as a digital reward for specific self-feeding actions (design principle 2). The visual feedback is not overly distracting (design principle 3). The LEDs are activated by the caregiver, using a custom remote switch. This allows caregivers to trigger the visual feedback as appropriate, and to adapt the feedback to the cognitive and motor ability of each child (design principles 4 and 5).

The tray was built with an Arduino prototyping microcontroller, powered by 4 AA batteries. Ten LEDs in various colors were wired for individual control (see Figure 1, right). A black cloth and a bag of soft material were attached to the back of the tray to cover the electronics.

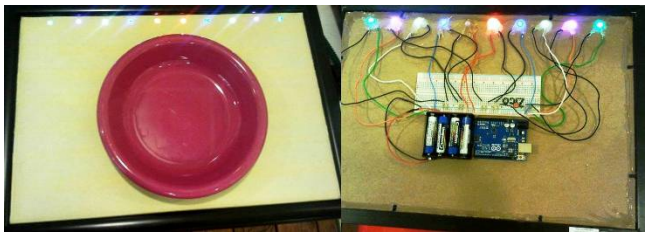

Figure 1. Version 1 of the ExciteTray prototype. Left: top side. Right: bottom side (uncovered).

We minimized potential risks related to the use of the tray with the following measures:

- The tray is battery-operated and does not require high-voltage electricity.
- All electronics were completely isolated, preventing the child from any direct contact with these parts.
- The LEDs on the top side of the tray cannot become heated and are not dangerous in any way; but, as a general precaution, they were covered with clear tape so the caregiver or child could not touch them directly.
- The tray's materials include wood, plastic and glue that are safe for children, with no toxic materials.
- The tray was designed with protective plastic and cloth covering over the LEDs, electronic parts, and batteries to protect those parts from the spilling of any liquids or moist foods during the meal.

3.3 User Study

A user study was conducted in order to validate the preliminary design principles, and to evaluate children's self-feeding behavior while using the tray. The study focused on the action of scooping food from the plate. This specific action was selected because it was previously described by experts as especially difficult for children.

In the field of occupational therapy, understanding typical development is the foundation to understanding and detecting diversity or disability [6]. Similarly, we need to understand how typically developing children respond to ExciteTray, as a baseline that will allow us to understand the responses of children with CP. Therefore, the user study reported here was conducted with typically developing children.

3.3.1 Participants

Four typically developing children (2 boys, 2 girls), 16-24 months old, participated in the study. Parents signed informed consent forms for their children prior to participating in the study.

3.3.2 Method

The study was conducted by a senior occupational therapist, experienced in feeding children of this age group. She conducted a feeding session using ExciteTray with each child at his or her home. All sessions were videotaped. Parents prepared food for their child and remained nearby. They were instructed not to react to the tray themselves, to prevent them from influencing their child. At the beginning of the session, the therapist demonstrated to the child how the tray works, and explained that "every time you scoop food from the plate, the tray will light up". This explanation was intended to clarify the cause-and-effect relationship between the scooping event and the lighting up of the tray. Using a "Wizard of Oz" methodology, the therapist operated the tray herself with the remote switch. She activated the LEDs whenever scooping occurred. The session ended when all food was consumed, or when the child signaled that he or she had finished the meal (usually after 3 to 6 minutes).

3.3.3 Results and Discussion

Video recordings were independently analyzed by two researchers. We present the results according to the five design principles we aimed to validate:

Do children pay attention to the tray? Directing one's gaze towards the tray was the main indication of paying attention to the tray. One boy and one girl consistently directed their gaze towards the tray whenever it lit up. The boy (the oldest participant, who had the highest level of ability) also said "lights", and "tested" the tray's feedback by delaying the insertion of the spoon to his mouth. These two behaviors were only observed once. In contrast, the other two participants only directed their gaze towards the tray sporadically, often missing occurrences when it lit up. In sum, it appears that the lights do not draw enough attention towards the plate.

Does the tray motivate self-feeding? Even when the lights were noticed by the children, they did not appear to be sufficiently motivating to serve as digital rewards.

Does the tray distract children from eating? Noticing the tray light up did not distract any of the children from self-feeding, they simply looked at the lights as they kept scooping food and bringing it towards their mouth.

Does the tray facilitate face-to-face interaction between caregiver and child? The therapist served as the caregiver during the study. Even though she was in charge of operating the tray using the remote switch, she was able to focus on the children and communicate with them during the sessions. For example, she called their name if they were distracted by a loud noise outside, or encouraged them to eat more. The children often looked at her as they ate, establishing eye contact, and responded to her when she talked to them. In sum, it appears that ExciteTray does not obstruct the interaction between caregiver and child.

Can a caregiver adapt the feedback to the individual abilities of each child? The caregiver used a remote switch to activate the LEDs when desired, in this case when scooping occurred. The visual feedback could be activated to reward any other self-feeding action. This enables caregivers to adapt the feedback to various ability levels, for example: reward simple actions while feeding children with a low level of ability, and more complex actions while feeding children with a higher level of ability.

3.4 Second Prototype

Overall, the results of our initial user study were promising. We observed face-to-face interaction between caregiver and child while using the tray. In addition, the tray was revealed as easy to operate at the discretion of the caregiver, thus adaptable to different levels of ability, and it did not distract children from eating. However, the LED feedback did not draw enough attention to the plate, and did not seem to be sufficiently motivating. Following these findings, we redesigned the tray. In the second iteration of the ExciteTray prototype the LEDs have been placed in a circular display at the center of the tray, surrounding the plate area (see Figure 2). The LEDs were covered by a clear acrylic layer, producing a more dominant yet soothing visual effect. In addition, we added a sunken plate-holder area, to ensure that the plate is leveled with the tray surface and does not block the child's view of the lights. Our next step is examining whether the new design is indeed more engaging for typically developing children. Once this step is accomplished, we will conduct in-depth studies with children with CP.

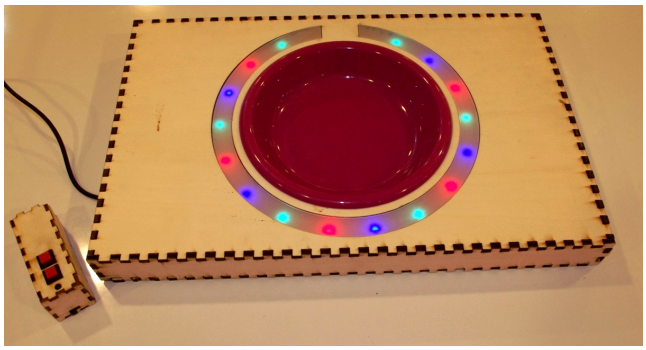

Figure 2. Version 2 of the ExciteTray prototype.

4. FUTURE WORK

We plan to continue with the prototype development process, and to incorporate sensors for automatic detection of specific self-feeding related behaviors (e.g. scooping, lifting). We also plan to develop tools for caregivers to assign specific feedback to each behavior. In that manner, detected behaviors will be automatically rewarded with pre-selected feedback. Since manual operation will no longer be required, caregivers could focus on the interaction with the child, or could supervise the feeding of several children simultaneously, as is often required in daycare settings.

The sensor for automatic detection of self-feeding behaviors will be a digital spoon that communicates with ExciteTray. The spoon will be used to both detect and measure eating-related movements, thereby providing caregivers with diagnostic data

regarding each child. To date, insufficient information is available regarding the skills required to enable a child to eat independently, nor the factors that impinge upon or delay independence. Little data exists concerning the biomechanics of grasping utensils or the food and bringing it to the mouth, control over the activity kinetics and issues related to motor planning and learning. The digital spoon could provide caregivers with this valuable information.

5. CONCLUSION

Children with developmental disabilities encounter great difficulties acquiring self-feeding abilities. We set out to develop an assistive technology aimed to motivate them in the process of mastering self-feeding. In this paper we described the initial design and implementation of "ExciteTray" – an early-stage prototype of a digital food tray, which rewards self-feeding with visual feedback in the form of colorful lights. ExciteTray was designed based on principles derived from interviews with domain experts: (1) draw the child's attention to the plate; (2) motivate the child during the various stages of self-feeding; (3) avoid or prevent distractions; (4) facilitate face-to-face interaction between caregiver and child; (5) allow caregivers to adapt the feedback to the individual cognitive and motor ability of each child. A prototype based on these principles was evaluated in a preliminary user study, following which a second version of the prototype was created. The second version of ExciteTray was designed to draw greater attention towards the plate, and to be more engaging for children. Future work includes additional user studies, as well as automatic detection and measurement of self-feeding behaviors using a digital spoon.

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7. REFERENCES

[1] Arverdson, J. C., and Brodsky, L., Eds. 1993. Pediatric swallowing and feeding: Assessment and management. Singular Publishing Group Inc., San Diego, CA.

[2] Bax, M., Goldstein, M., Rosenbaum, P., Leviton, A., Paneth, N., Dan, B., Jacobsson, B., and Damiano, D. 2005. Proposed definition and classification of cerebral palsy. Dev. Med. Child. Neurol. 47(8), 571-576. DOI= 10.1017/S001216220500112X.

[3] Chiu, M-C., Chang, S-P., Chang, Y-C., Chu, H-H., Chen, C. C-H., Hsiao, F-H., Ko, J-C. 2009. Playful Bottle: A mobile social persuasion system to motivate healthy water intake. In Proceeding of the 11th International Conference on Ubiquitous Computing (Orlando, Florida, USA, September 30 - October 03, 2009). UbiComp '09. ACM, New York, NY, 185-194. DOI= 10.1145/1620545.1620574.

[4] Cokrill, H. 2009. Feeding. In Finnie's handling the young child with cerebral palsy at home, E. Bower, Ed. Butterworth Heinemann Elsevier, UK, 149-164.

[5] Comber, R., Ganglbauer, E., Choi, J. H-J., Hoonhout, J., Rogers, Y., O'Hara, K., and Maitland, J. 2012. Food and interaction design: Designing for food in everyday life. In Extended Abstracts on Human Factors in Computing Systems (Austin, Texas, USA, May 5 - 10, 2012). CHI EA '12. ACM, New York, NY, 2767-2770. DOI= 10.1145/2212776.2212716.

[6] Delaney, A. L., and Arvedson, J. C. 2008. Development of swallowing and feeding: Prenatal through first year of life. Dev. Disabil. Res. Rev. 14(2), 105-117. DOI= 10.1002/ddrr.16.

[7] Illingworth, R. S. 1980. The Development of the Infant and young child: Abnormal and normal (7th ed.). Churchill Livingstone, London, UK.

[8] Kadomura, A., Li, K. C-Y., Chen, A. Y-C., Chu, H-H., Tsukada, K., and Siio, I. 2013. Sensing Fork and persuasive game for improving eating behavior. In Proceedings of the ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication (Zurich, Switzerland, September 8 - 12, 2013). UbiComp '13 Adjunct. ACM, New York, NY, 71-74. DOI= 10.1145/2494091.2494112.

[9] Kadomura, A., Li, K. C-Y., Chen, A. Y-C., Nakamori, R., Tsukada, K., Siio, I., and Chu, H-H. 2013. Sensing Fork: Eating behavior detection utensil and mobile persuasive game. In Extended Abstracts on Human Factors in Computing Systems (Paris, France, April 27 - May 2, 2013). CHI EA '13. ACM, New York, NY, 1551-1556. DOI= 10.1145/2468356.2468634.

[10] Kadomura, A., Tsukada, K., and Siio, I. 2013. EducaTableware: Computer-augmented tableware to enhance the eating experiences. In Extended Abstracts on Human Factors in Computing Systems (Paris, France, April 27 - May 2, 2013). CHI EA '13. ACM, New York, NY, 3071-3074. DOI= 10.1145/2468356.2479613.

[11] Lo, J-L., Lin, T-Y., Chu, H-H., Chou, H-C., Chen, J-H., Hsu, J. Y-J., and Huang, P. 2007. Playful Tray: Adopting ubicomp and persuasive techniques into play-based occupational therapy for reducing poor eating behavior in young children. In Proceeding of the 9th International Conference on Ubiquitous Computing (Innsbruck, Austria, September 16 - 19, 2007). UbiComp '07. Springer-Verlag, Berlin, Heidelberg, 38-55.

[12] Morris, S. E., and Klein, M. D. 1987. Pre-feeding skills: A comprehensive resource for feeding development. Communication Skill Builders, Tucson, AR.

[13] Rosenbaum, P., Paneth, N., Leviton, A., Goldestein, M., and Bax, M. 2007. A report: The definition and classification of cerebral palsy April 2006. Dev. Med. Child. Neurol. 49(s109), 8-14. DOI= 10.1111/j.1469-8749.2007.tb12610.x.

[14] Sugden, D., and Wade, M. 2013. Typical and atypical motor development. Mac Keith Press, London, UK.

[15] Thelen, E., Kelso, J. A. S., and Fogel, A. 1987. Self-organization system and infant motor development. Dev. Rev. 7(1), 39-65. DOI= 10.1016/0273-2297(87)90004-9.

[16] Weir, K. A., Bell, K. L., Caristo, F., Ware, R. S., Davies, P. S., Fahey, M., Rawicki, B., and Boyd, R. N. 2013. Reported eating ability of young children with cerebral palsy: Is there an association with gross motor function?. Arch. Phys. Med. Rehab. 94(3), 495-502. DOI= 10.1016/j.apmr.2012.10.007.