Assisting Caregivers of Children with Cerebral Palsy: Towards a Self-Feeding Assessment Spoon

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Abstract
Many children with cerebral palsy (CP) encounter great difficulties mastering self-feeding. We set out to assess the self-feeding skills of young children with CP via a novel instrumented spoon that monitors upper extremity biomechanics involved in eating. We describe the initial stages of an iterative design process, consisting of a focus group with domain experts, and rapid-prototyping. We discuss the physical, assessment and safety requirements for the spoon. In addition, we explain the potential of tangible interfaces to provide professional caregivers with valuable information regarding each child.

Author Keywords
Cerebral palsy; self-feeding; assessment; children; tangible user interface.

ACM Classification Keywords
K.4.2. **[Computers and Society]:** Social Issues - Assistive technologies for persons with disabilities.

General Terms
Design, Human Factors, Measurement.

Introduction

Eating is a complex process with physiological, biomechanical, and behavioral aspects involving the entire body [13]. Typically developing young children gradually shift to higher levels of independent eating, until eventually mastering self-feeding, usually by the age of three years [8, 13, 15]. Disruption in eating may lead to malnutrition, poor growth, developmental delay and loss of general health and well-being [1]. Children with cerebral palsy (CP) often have significant difficulties mastering self-feeding [4, 16]. 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 [14]. Motor impairment may be accompanied by a seizure disorder and by disturbances of sensation, cognition, communication and behavior [2].

To date, little data exist concerning the biomechanics of grasping utensils or food and bringing it to the mouth, control over the activity kinematics and kinetics, and issues related to motor planning and learning among children with CP. Tangible user interfaces have the potential to provide such data, thereby making valuable assessment information about each child available to caregivers. Quantitative assessment data will lead to more effective treatment of self-feeding difficulties.

We set out to assess the self-feeding skills of young children with CP via a novel instrumented spoon that monitors several biomechanics variables of the upper extremity involved in self-feeding. The spoon, called SenSpoon, is currently being developed in an iterative and participatory design process, consisting of a focus group with domain experts and rapid-prototyping. In this paper we describe the expert-based design process, present our initial prototype, and discuss avenues for future work.

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, with or without disabilities, due to developmental and safety concerns.

EducaTableware [11] are interactive tableware devices (fork and cup) intended to make eating more enjoyable by emitting sounds when a child eats or drinks. Sensing Fork [9, 10] 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. HAPIfork [7] is an electronic fork that tracks eating speed. It vibrates when the user eats too fast, thereby promoting slower and healthier eating. 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 [12] aims to reduce meal completion time with a weight-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 CP and similar developmental disorders. To the best of our knowledge, the only eating-related system designed specifically for children with CP was previously presented by our team [6]. The system, called ExciteTray, is a digital food tray that rewards self-feeding with visual feedback in the form of a colorful light display. It is aimed to motivate young children with CP throughout the gradual process of acquiring independent eating skills.

The SenSpoon extends our previous work by focusing on the needs of professional caregivers, assisting them with assessing the self-feeding skills of children with CP.

System Design Process

SenSpoon is being designed by an interdisciplinary team consisting of HCI researchers, an occupational therapist specializing in CP management, a rehabilitation technology researcher, and an industrial designer. We set out to develop a technology that provides professional caregivers with data concerning the biomechanics of upper extremity involved in eating. Our first step entailed consultation with caregivers who treat children with developmental disabilities in order to learn more about their and the children's needs and requirements.

Participants

Six professional caregivers (3 occupational therapists and 3 physiotherapists) participated in a focus group. Their years of experience range from 18 to 40. All participants regularly assess the skill level of children with disabilities. They were recruited through personal acquaintance with one member of the research team.

Method

Participants were invited to participate in a focus group on assessing self-feeding skills among children with CP, using a novel instrumented spoon. The session lasted approximately two hours. First, participants filled out a questionnaire regarding their professional experience, current use of assistive technologies, and challenges they face when assessing the skill level of children. Second, an industrial designer facilitated a group discussion regarding the physical requirements for the spoon (size, shape and material). Third, an HCI researcher facilitated a group discussion regarding the assessment requirements for the spoon. Lastly, participants were asked to envision what type of output they would like to receive from the spoon, and draw the desired graphical representation of this output. The session was audio recorded with participants' consent. The recordings were later transcribed and independently analyzed by two researchers to identify emerging common themes.

Results and Discussion

Use of assistive technologies: two participants use assistive technologies (e.g., biofeedback, virtual reality); none currently use eating-related assistive technologies.

Challenges for assessing the skill level of children: how to accurately and rapidly map the capabilities of each child in order to devise a treatment plan, how to assess children in real-time during routine daily activities, rather than in a clinical setting.

Potential benefits of technology-based assessment: automated, provides quantitative data, enables customization of treatment plan, engaging and motivating for children.

Potential challenges of technology-based assessment: may be perceived to replace actual therapy or

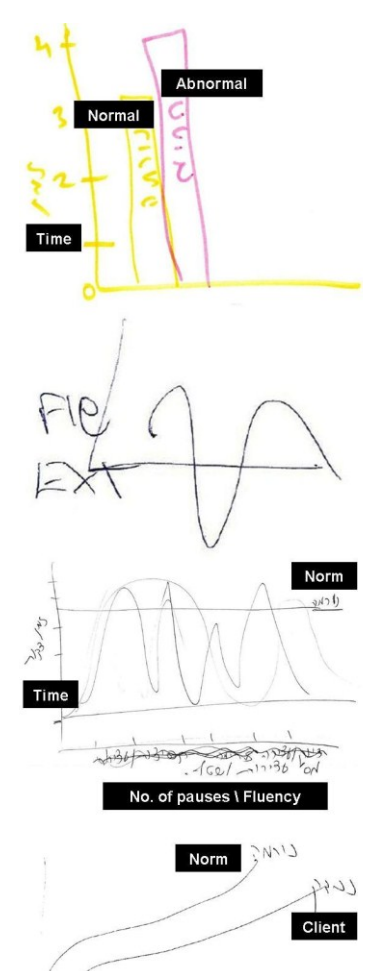

Figure 1. Drawings by caregivers depicting desired output from the spoon. Tags in white font provide translation for non-English text.

interaction with the child, not all caregivers are open to using technology.

Physical requirements for the spoon: must be safe, comfortable to hold, with a size, depth and angle that match the needs of the child. All participants agreed that the spoon should be made out of plastic or silicone, preferably in a neutral color.

Assessment requirements for the spoon: participants would like to monitor the following variables: accuracy, fluency and smoothness of movement, grip force, trajectory from the plate to the mouth, speed of movement, duration of meal, amount of food consumed.

Desired output of the spoon: most participants envisioned the output of the spoon as a series of graphs, comparing various aspects of the child's motor behavior to normative data *("The graph should compare my client to the norm, here's his curve and here's the norm"*). Moreover, the graphs must be simple and easy to comprehend, providing caregivers with a quick overview or snapshot of the child's skill level (*"I need something that is visually simple. I can't waste a lot of time on this, I want to see a screen that immediately displays time and compares fluency"*). See examples of participants' drawings in Figure 1.

Hence, in order to meet the needs of professional caregivers, the optimal design will: (1) utilize several types of sensors to monitor various biomechanical variables during self-feeding, (2) create a plastic or silicone spoon customized to contain all electronic parts, (3) develop an algorithm for integrating and analyzing sensor-based data, and (4) design a graphical user interface for presenting the results of the analysis in a clear and meaningful manner.

Initial Prototype

The SenSpoon uses the IMUduino BTLE board (http://www.femtoduino.com/spex/imuduino-btle) for sensing and communication. This 40x16mm Arduino clone includes a 3-axis gyroscope, 3-axis accelerometer, and 3-axis digital compass. The board also contains a Bluetooth Low Energy chip, which we pair wirelessly with an Android phone to perform data logging. The phone receives the streamed data in realtime, leaving open the possibility of realtime analysis and feedback.

For the initial prototype, a pre-clinical feasibility test, we taped the IMUduino to the handle of an off-the-shelf metal teaspoon, rigging a holder for the five LR44 button cell batteries used to power the board. The assemblage was covered in a plastic sheath for water resistance (see Figure 2). Total weight was 36 grams, no heavier than a stainless steel teaspoon.

Safety Considerations

In order to ensure that the SenSpoon is safe to use, we implemented the following measures: (1) the spoon is battery-operated and does not require high-voltage electricity, (2) all electronics are completely covered, preventing any direct contact between the electronic parts and the child and moist foods, (3) all surface materials are non-toxic, (4) data transmission from the spoon is wireless to prevent tangling of cables while eating. Furthermore, we consulted the head of a bio-medical engineering department at a major medical center. He examined the prototype, and gave written approval that it is safe to use.

Figure 2. Initial prototype of SenSpoon: a standard spoon augmented with the IMUduino BTLE board to monitor various biomechanical variables during self-feeding. Data is streamed via Bluetooth to a smartphone.

Future Work

We are currently in the process of monitoring self-feeding behaviors of healthy adults using the initial spoon prototype, and developing an algorithm for analyzing sensor-based data. Our next step is the design and creation of a customized plastic or silicone spoon, into which all electronic parts will be incorporated. We will then monitor the self-feeding skills of children with CP as well as typically developing children, in order to establish the discriminant validity of the spoon. As an assessment tool, the spoon should be able to differentiate between children with CP and typically developing children based on upper extremity biomechanical variables. Eventually, the final prototype will be used as an assessment tool for professional caregivers. The final prototype may also assist with treatment for self-feeding difficulties, optimally through integration with other self-feeding assistive technologies, mainly our digital food tray described in [6]. Leveraging tangible interaction for augmenting current clinical practice is expected to benefit both professional caregivers and children with disabilities.

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