# Investigating A Notifying Utensil for the Eating Needs of People with Cerebral Palsy

James Nguyen and Debbie Yuen
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**Abstract**

Cerebral Palsy (CP) is a group of neurological disorders that affects a person's motor skills such as body movement, muscle coordination, and balance. It has various levels of severity and a variety of symptoms. There is no cure for CP, but there are assistive devices and methods used to help those with CP live their daily lives, including assisting in the eating of food. Through an interview with an individual with CP as well as difficulty feeding themselves independently, the desire to become more independent in this aspect was conveyed. With this insight into this individual's needs, we hypothesize that an eating utensil that notifies users of an unhealthily fast eating pace as well as food that is too hot to safely consume will allow users with CP to become more independent while eating. A functional prototype of this utensil was constructed, utilizing a microcontroller and the required sensors for these functions. A study is proposed where participants with CP will eat using the device and express their thoughts in a questionnaire. If the hypothesis is supported, this may promote the development of assistive technology incorporating these notifying elements and may lead to the greater independence of people with CP.

## I. Introduction

In this report, we address how adults living with cerebral palsy can safely eat and be fed food. We have chosen the domain of independently eating because it is a right to every human being and consuming food is an everyday self-care routine. Our objective is to challenge how eating utensils can be designed differently to allow those who depend on others for nutritional needs to gain control of eating on their own. This report investigates the physical, emotional, and social, and psychological benefits of independent eating and how eating utensils can be redesigned to meet user needs.

### *A. Background*

Historically, people with disabilities have fought for opportunities to be independent. While independence has a uniquely different definition to each individual, it is a human right to live with or gain a sense of freedom and control in who they are [6]. Everyday tasks such as independent eating are important components to our physical, social, and emotional well being [7]. Independent eating can increase self-esteem and decrease feelings of being a burden and dependence in those who are unable to feed themselves. This association with greater independence and control over consuming food have profoundly empowering effects [8].

Cerebral palsy is a group of neurological conditions that affect individuals of all ages [1]. People with cerebral palsy may have various levels of severity and combinations of symptoms that affect their abilities to move, eat, and communicate [2] [3]. Feeding difficulties are prevalent amongst people with cerebral palsy. Individuals with cerebral palsy who are unable to communicate on their own to feed themselves have a lower life-expectancy due to poor nutritional care [10]. This is a major challenge that needs to be addressed in order to increase the quality of life and independence of people with disabilities and their caregivers [5]. Feeding problems may result in nutritional deficiencies that impact oral motor impairment, swallowing dysfunction, and other growth problems [10]. Required feeding assistance has also brought up other feeding dysfunction concerns such as choking, vomiting, constipation, and long and difficult feeding sessions [10]). Independent eating in addition to nutritional support while consuming food are only two reasons why designing new technological experiences to support individuals with cerebral palsy and their caregivers in safely and independently consuming or feeding food [4].

Currently, there are many technologically advanced eating utensils that provide stable support to individuals eating. Such spoons include the Google Liftware spoon that helps people with limited hand and arm mobility to eat with less difficulty by minimizing the amount of shaking [9]. While stabilizing utensils may benefit people with cerebral palsy, our report focuses on addressing overeating, eating at a unhealthily fast pace, and eating in a safe manner. HAPIfork is a fork that focuses on eating slowly; however, its focus is to support its users in improving eating behavior to lose weight. Instead of designing an eating utensil for weight loss, we aim to design for people with disabilities who need support in realizing food safety and achieving independence while eating.

Our hypothesis is that our technologically advanced eating utensils will help remind and teach individuals to recognize when food is hot. In addition, the utensils will prevent gastric problems by notifying individuals that their eating or feeding pace is unhealthily fast. This collectively will promote safe and independent eating.

### B. Overview

We propose using secondary resources to further our knowledge on assistive technologies, autism spectrum disorder, and cerebral palsy. Referencing research papers and reading about different perspectives in this realm is important in understanding our need knower and her needs. In addition, our interview with our need knower alongside her mother and caregiver will give us perspective into the need knower's life, personality, and conditions. In the following paragraphs, we will begin by talking about our interview results and the user needs we gathered through the 2 hour interview session with the need knower and her family. Then, we will follow with our utensil design and implementation.

## II. Preliminary results

Our need knower is a female in her late twenties with dyspraxia and severe autism. We interviewed our need knower with her mother and one of her caregivers. Our goal during the interview was to understand the need-knower, caretaker, and the mother. Cerebral palsy has impacted her bowel movements and dietary needs that have been beneficial in maintaining healthy bones and muscles. Having severe autism, our need knower is nonverbal and communicates via an iPad and her uniquely own gesture language.

In the present case, our need knower has impaired motor skills and needs support in completing activities. Some activities include swiping on the iPad or communication device, playing board games, consuming food, watering plants, participating in Zoom class, and doing laundry. The need knower's assistive technologies give the need knower and her support team clarity on what their thoughts and feelings are. The opportunity to independently complete tasks such as eating on her own and feeding her parents is important for the participant's sense of independence and freedom. As a result, we have proposed widely smart eating utensils that may serve the participant in engaging in independent eating and cooking classes over Zoom.

Currently, the need knower's virtual cooking classes take place once a week with one of her special education teachers. On Fridays, she volunteers with the nonprofit organization, Meals on Wheels. For every meal, the need-knower eats with her family where both of her parents slowly feed her at a slow food. While our need knower is capable of stabilizing and holding a spoon, she is usually fed by her parents or caregiver. This is because when she eats by herself, she eats too fast and ends up choking, making a huge mess, and a bad stomach ache. Our need knower feels sick following her overeating episodes. Because she is nonverbal, she is unable to communicate her pain with words, which may prompt behavioral problems and bathroom accidents.

We hope to support our participant in independently eating her meals and snacks. Eating independently without having to be fed by a parent or caregiver is difficult. Keeping the food within her spoon, eating at a slower rate to prevent stomach aches and vomiting, and burning her mouth with hot foods are challenges our participant experiences. She currently consumes food with the support of a caregiver or family member. However, this approach lessens her freedom and independence.

## III. Methods

*Device Concept:* In order to test the effect of speed/acceleration and temperature monitoring functions in a utensil, we developed an assistive utensil device that uses a microcontroller and sensors to notify if the user is eating too quickly or if the food is too hot in a discrete manner, using vibration. As shown in Fig 1, the device includes a handle attachment to a typical utensil, that uses a microcontroller, accelerometer, temperature sensor, and vibration motor, to give vibrations to notify the user. Users would grip onto the elliptical handle of the housing to grasp the device and would hold it similar to how they would a typical utensil. The microcontroller would be programmed to take in the information obtained from the sensors and process that information based on a finite state machine, and then would control a vibration motor that the user would feel, based on the data obtained by the sensors. This device would potentially allow the user to become more conscious of their eating speed as well as the temperature of the food.

Fig. 1. Outside view of the prototyped utensil handle attachment device.

*Subsystem description/Proof of function:* The device components are shown in Figs. 2 and 3. The handle casing/housing was 3D printed as two semi-elliptical parts with spaces to place all the other components of the device. The utensil was placed in the housing with a snap fit manner. The accelerometer was directly connected and slotted under the microcontroller eliminating the need for additional pin connections. The temperature sensor and vibration motor were soldered to the microcontroller with auxiliary wires and the latter was used in tandem with a transistor and resistor. The temperature sensor was placed in contact with the utensil on its distal end, next to the utensil's base and secured with electrical tape. The vibration motor was placed on the bottom face of the original utensil handle with adhesive and was slotted into a custom hole in the housing.

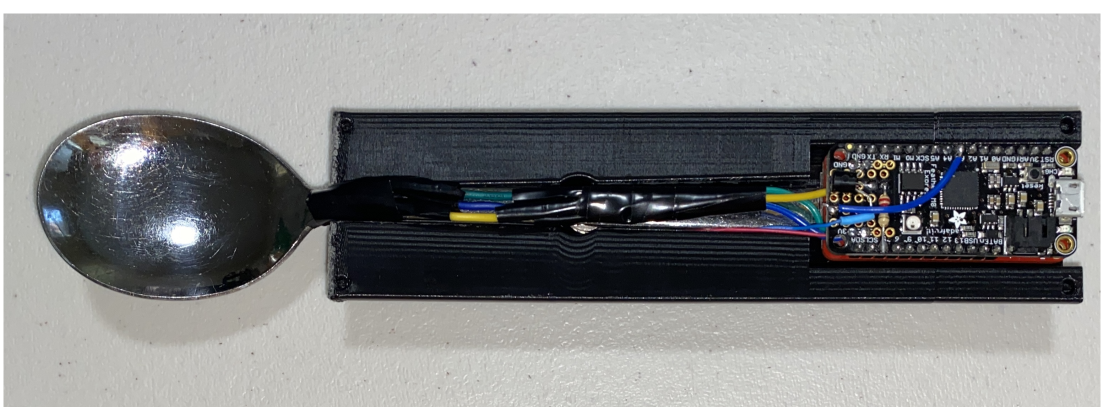

Fig. 2. Top view of the prototyped utensil handle attachment device.

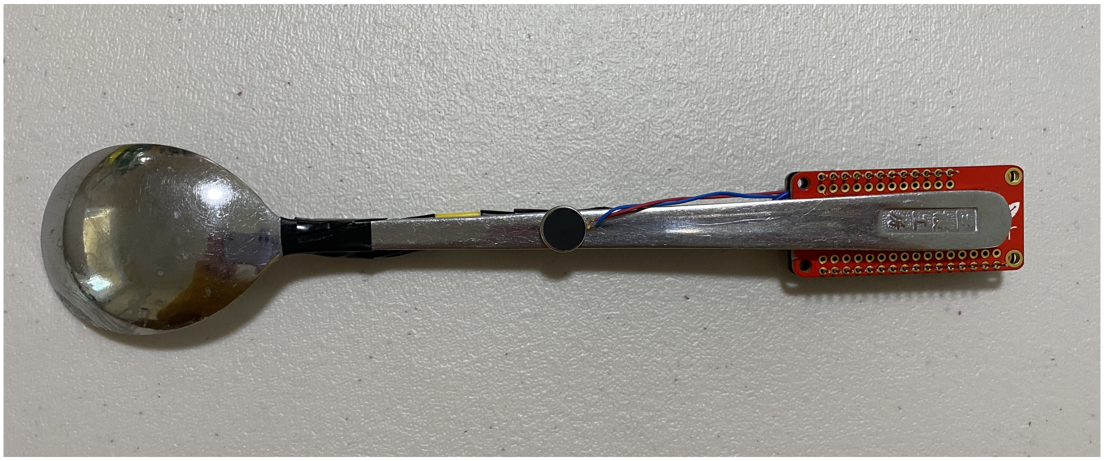

Fig. 3. Bottom view of the prototyped utensil handle attachment device.

This design illustrates the use of simple sensors and a simple design with a function state machine in place. The specific components were chosen with an emphasis on compactness. The accelerometer connects directly below the microcontroller and contributes to virtually no additional space. The vibration motor is about a centimeter in diameter and less than that in thickness. The temperature sensor is of similar shape to a transistor. Because of this decision, the performance of the temperature sensing is weaker and more delayed than intended. While the design at this point shows proof of concept of a device that tracks one's eating pace and food/utensil temperature, other methods and components may be used to improve the sensing capabilities of such a device.

| | (1) Strongly disagree | (2) Disagree | (3) Neutral | (4) Agree | (5) Strongly Agree | (0) N/A |
|---|---|---|---|---|---|---|
| The device vibrated enough to catch my attention at every instance it vibrated | | | | | | |
| The device helped me not burn myself while eating | | | | | | |
| The device vibrated an appropriate amount of times | | | | | | |
| The device is not more uncomfortable than the normal utensil I use | | | | | | |
| I would prefer this device over the typical utensil I use | | | | | | |
| I would use this device for my meals | | | | | | |
| Thoughts, Feedback, Space to clarify any answers above | | | | | | |

Fig. 4. Proposed study questionnaire for study participants.

*Proposed study:* 10 participants will be voluntary subjects for this study. The participants will include a range of people with CP and/or gastric problems due to pace of eating or a decreased recognition of food temperature. In order to participate, the subject must satisfy the following qualities: i) ability to grasp the device in a manner sufficient for eating, ii) ability to chew and process food, iii) ability to convey opinions about an eating experience. These qualities were given to ensure the participants' abilities to perform the procedure of the study. The focus of this study will be the use of the utensil device to eat a given meal. To do this participants will be given a meal and a 30 minute period to finish it, if not finished after 30 minutes participants will be asked to proceed to the next part of the study. The participants will then be given a questionnaire utilizing the Likert scale. Due to the subjective nature of the scale, the participants will be given statements related to comfort and perceived helpfulness of the device and comparison to a typical utensil. Another section of the questionnaire will allow the participants to write out their thoughts and feedback and not be restricted to the Likert scale. An example of the questionnaire is shown in Fig. 4.

Upon arrival, the participants will be asked to enter a room with a moderate climate where a meal will be provided and the utensils used will include our handle attachments. The participant will be informed that they have 30 minutes to eat the meal at their own pace, and will have no obligations to finish before the 30 minutes has elapsed. After that time has elapsed they will be asked to finish the questionnaire and will be free to go thereafter.

We plan to submit a protocol for review through the Internal Review Board for the Protection of Human Subjects. We have completely the CITI training Group 1: Biomedical Research Investigators as of 05/08/2022.

## IV. Intellectual Merit

With the proposed study above, we will be able to illustrate the effect that eating pace and temperature notification, as well as the comfort of our specific device has on people with CP and gastric problems stemming from eating pace. This initial design of such a device can validate the preliminary use of a combined eating pace and food temperature sensing assistive utensil. This can also inspire others in the community to pick up this concept and improve upon the works described here or even to just work within the field of assistive devices dealing with food consumption. This concept however does require more testing and validation to ensure that it satisfies the user needs. These insights on speed/acceleration and temperature tracking and also be implemented into other assistive devices that help in other aspects of people's lives.

## V. Broader Impact

This study shows the concept of an assistive technology and device that can positively impact those with CP whose dexterous eating functions and habits are affected. This kind of device may also benefit those who are simply less conscious about their utensil movement frequency or the temperature of the utensil/food that they are consuming. The adoption of this device can allow those who are similarly affected by CP. This would ultimately help those affected to make strides in eating meals more independently and more confidently. This device can also be a method to kickstart further ideas to create similar devices and because this device is relatively simple, the design can be recreated for those who may want to use the device. In all, the use of this device can lead to a feeling of independence for those affected.

## References


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# Appendix A
# Discovery Decomposition

*Topic of the interview: everyday manual activities with hemiparetic stoke.*

*1) High-level motor skills assessment for ambulant children with cerebral palsy: a systematic review and decision tree:* [1].

- Background/Hypothesis: The aim of this study is to investigate school-aged children with cerebral palsy (CP) to collect evidence and data for high-level motor skill assessment tools.
- Methods: The researchers searched for the population of children with CP aged 5 - 18y, assessment focus (high-level motor skills), and psychometric evidence in five databases. They then evaluated the strength of their evidence using the number of studies, quality, and conduct according to COnsensus-based Standards.
- Results: 39 studies or 11 assessments met the criteria. The decision tree was developed with five levels: clinical feasibility, relevance, tool design, clinical utility, and psychometric properties.
- Conclusion: For school-aged children with cerebral palsy, it was concluded that high-level motor skill assessment tools are beneficial with strong psychometric evidence. These results may help inform clinicians and researchers in identifying appropriate tools to measure high-level motor skills in children with cerebral palsy.
- Test Hypothesis: The assessment tools show high clinical utility and ability to detect motor skills for ambulant, school-aged children with cerebral palsy.

*2) Eye–hand coordination during manual object transport with the affected and less affected hand in adolescents with hemiparetic cerebral palsy:* [2].

- Background/Hypothesis: Cerebral palsy is a group of disorders that impact movement and posture. Cerebral palsy may result in activity limitations due to damage to the brain. A subtype of cerebral palsy includes spastic hemiparesis, in which unilateral lesions to the cerebral cortex or corticospinal pathways are affected. It is hypothesized that individuals with cerebral palsy would use more visual monitory while performing tasks with their affected hands and that gaze patterns are less anticipatory in individuals with cerebral palsy.
- Methods: This study recruited 16 individuals. In the experimental group, 6 participants had hemiparetic cerebral palsy. Hand and head movements were recorded using an Optotrak 3020 system with a sampling rate set at 125 Hz.
- Results: The study conducted a total of 600 trials (15 x 40). Compared to control participants using their hands, participants with cerebral palsy had shorter movement termination asynchrony and a higher number of intermediate fixations.
- Conclusion: In the experimental and control groups, the participant's gaze usually departed from the object region after the hand movement began. They also found evidence to support their hypothesis that individuals with hemiparetic cerebral palsy increase visual monitoring of manual actions when using their affected hand.
- Test Hypothesis: The main question they pursued was that participants with cerebral palsy would be more likely to closely monitor actions performed with their affected hand compared to those who did not have an affected hand.

*3) Inclusive design-assistive technology for people with cerebral palsy:* [3].

- Background/Hypothesis: There has been a lot of research done on using ICT (information and communication technologies) to have people with less motor functionality to be more inclusive. The paper provides background on cerebral palsy, a "brain damage sequel disorder".
- Methods: This paper uses user-centered design to provide ICTs that can enhance the inclusion of those with cerebral palsy and uses Vogtsky's Sociocultural Theory to guide their methods.

- Results: Students who used the new technologies developed improved psychological processes towards social interaction, autonomy, and participated in class activities more efficiently. Students with cerebral palsy performed poorly with timed tasks.
- Conclusion: The paper verified the importance of new technologies in a class setting and that improvising the inclusion of students with disabilities in a class setting is a real possibility. The paper also discouraged creating timed tasks. The paper concludes that ICT is both helpful for students and teachers to help in the process of inclusion.
- Test Hypothesis: Students presented with ICT will be more included in a classroom setting.

*4) Low cost assistive technology to support educational activities for adolescents with cerebral palsy:* [4].

- Background/Hypothesis: The paper provides background on assistive technologies (devices used to assist individuals with disabilities or the elderly) and wants to find whether these help those with cerebral palsy using low-cost material.
- Methods: The paper created a survey and observed 4 participants with CP to finish a specific task. The paper recorded the participant's actions and time to complete the task.
- Results: The results showed that participants scored the device as a 4.62 on a Likert scale, which means it is highly satisfactory, though only 4 participants were involved in the study.
- Conclusion: The assistive technology was able to effectively assist those with cerebral palsy.
- Test Hypothesis: The device receives a high satisfactory rating on the Likert scale from 4 participants.

*5) Reliability and validity of the eating and drinking ability classification system in adults with cerebral palsy:* [5].

- Background/Hypothesis: The goal of this study is to evaluate dysphagia in 117 adults with cerebral palsy. This is important because the eating process becomes may become more difficult as age increases, usually around or before age 30. As a result, they evaluated the reliability of the Eating and Drinking Ability Classification System (EDACS), as used by swallowing occupational therapists and caregivers.
- Methods: This study took place at non-profit adult programs or centers for people with disabilities that give individuals the opportunity to participate in exercises, hobbies, and art activities. All participants were asked to describe their mealtime experiences and swallowing frequency.
- Results: Mealtime duration and difficulties with eating duration were the determining factors in various eating levels at I and II.
- Conclusion: The EDACS is a reliable tool in classifying eating, drinking, and swallowing ability for adults with cerebral palsy.
- Test Hypothesis: The EDACS can help evaluate the interrater reliability between participants and care providers.

*6) Growing up with cerebral palsy: perceptions of the influence of family:* [6].

- Background/Hypothesis: This research study explores women with cerebral palsy's perceptions and thoughts of how their family contributed to their overall quality of life.
- Methods: This qualitative research study consisted of 8 women with cerebral palsy between ages 22 to 55 years. This study was conducted with a feminist biographical approach.
- Results: Participants shared important and rich contextual data that were categorized into 4 themes: being an advocate, teaching advocacy, promoting inclusion and acceptance, integrating therapy into daily life, and the importance of siblings as friends and mentors.
- Conclusion: The researchers discovered that healthcare professionals were instrumental in helping women with cerebral palsy and their respective families achieve the 4 themes. An example of such is teaching and guiding family members on how to be disability advocates.

- Test Hypothesis: The impact and importance of a family member's role in the lives of women with cerebral palsy.

*7) Different priorities: a comparison of parents' and health professionals' perceptions of quality of life in quadriplegic cerebral palsy:* [7].

- Background/Hypothesis: Feeding difficulties in children with quadriplegic cerebral palsy are common. Their goal in this study was to discover important determinants of feeding-related quality of life and to then compare those findings with the interpretations from healthcare professionals.
- Methods: This was a qualitative cross-sectional study with 4 focus groups of 21 parents of children with quadriplegic cerebral palsy. This study took place in a paediatric teaching hospital in Sydney, Australia.
- Results: Parents and healthcare professionals shared common perceptions that were clustered into the same 5 themes. These themes included: parent-child interaction; delivery of health services; the child's emotional well-being; the child's physical well-being, and socialization. However, the subthemes and values were different, resulting in different priorities for treatment. This created a negative effect between parents and healthcare professionals.
- Conclusion: The 5 themes from the study provided a framework in evaluating their child's health needs. Families hold an important, expert role in their child's emotional and social well-being.
- Test Hypothesis: In order to provide a reliable framework for evaluating health in a clinical setting, they must discover and explore parents' perceptions of feeding-related quality of life.

*8) I want to play: Children with cerebral ˜ palsy talk about their experiences on barriers and facilitators to participation in leisure activities:* [8].

- Background/Hypothesis: This research article considers the opinions of Spanish children with cerebral palsy when evaluating their experiences in leisure activities. In this study, they focus on considering the perspectives of children by exploring the barriers and facilitators of leisure activities.
- Methods: In this study, 16 children (aged 7 to 17 years) with cerebral palsy participated. The study took place in Spain.
- Results: Children with cerebral palsy reported that there were more barriers than facilitators that influenced their participation in leisure activities and that body functions also were barriers. These results provide important data in designing interventions for children with cerebral palsy.
- Conclusion: Physical, social, and attitudinal environments can be improved to include and enhance participation in leisure activities for children with cerebral palsy.
- Test Hypothesis: From the perspective of children with cerebral palsy, what barriers and facilitators are influencing how children with cerebral palsy participate in leisure activities?

*9) Verily Life Science Launches Liftware Level Device to Help People with Limited Hand and Arm Mobility Eat with Confidence:* [9].

- Background/Hypothesis: This article discusses the innovation Verily Life Sciences or Google Life Sciences. Google's Liftware aims to support individuals with motion-related disorders in independently feeding themselves.
- Methods: This report focused on announcing the 2nd iteration of Liftware to the public.
- Results: The Liftware team is continuing to create inventions to support users in comfortably and confidently consuming their meals with their friends and family.
- Conclusion: The world needs better designed eating utensils that include the needs of people living with movement disorders.
- Test Hypothesis: In order to verify that Liftware is a product users need, they will need to continue to do more testing and see how in demand the product is when released into the market.

*10) Feeding and Nutrition in Children with Neurodevelopmental Disability:* [10].

- Background/Hypothesis: Children with neurological impairments have been challenged with health problems related to feeding. Attentive nursing care while feeding is an essential for the growth of the child and important for decreasing gastrointestinal disorders.
- Methods: This book utilized up-to-date accounts and assessments that provide real life clinical problems. The book encompasses 6 scenarios that comment on 6 different participants with disabilities.
- Results: Feeding and the diets of children with neurodevelopmental disabilities are essential to their health and overall quality of life.
- Conclusion: Parents, caregivers, nurses, and anyone feeding children with neurodevelopmental disabilities need to be aware of how they feed children and what foods they give them.
- Test Hypothesis: Healthy and safe feeding habits will lead to healthier children with neurodevelopmental disabilities.

# Appendix B
# Investigational Device Details

You will put the details of your investigational device here.

## *A. Interpreting the interview results*

Refer to Fig. 5

| Customer Statement | Interpreted Need |
|---|---|
| Has a difficult time swiping on her iPad with her entire hand. | Needs help with swiping the iPad when interacting without her entire hand |
| Gets frustrated with her touch screen computer because the buttons are too small. | Buttons on devices need to be accessible for her hands |
| Unpacking and packing up her games and toys is difficult for her. | Needs support unpacking and packing up games and toys. |
| Has a difficult time using/holding food utensils, food falls out often. | Needs utensils that can effectively hold and handle food |
| Frequently drops or throws her bowls and plates. | Needs sturdy material for bowls, plates, etc |
| Has a difficult time taking on and off a zipped sweater | She needs support taking on and off a zipped sweater. |
| Has a difficult time keeping the iPad and devices up while using it while sitting/standing | Needs an iPad stand that helps her keep her iPad in place while she is standing and sitting. |
| Likes washing fruits and vegetables herself, but cant do it effectively | She needs assistance providing force and precise finger movements for washing f&v |
| Would like to water plants with a stable hose. | She needs support holding the hose when watering plants in the garden. |
| Likes to play games and needs support resetting her games or playing a second round | She needs assistance mixing her colored games. |
| Struggles to control shopping carts she pushes | Needs to assist grasp control and force application |
| Loves to pull luggage but many of the times she pulls them the wrong way | Needs assistance pulling luggages the correct way |
| Has difficulty brushing her teeth | Needs support reaching her back teeth. |
| Consistently takes off her seatbelt in the car because doesn't like them | Needs a seat belt for quick unbuckling but also prevents user from dismantling while driving. |
| Enjoys putting on her own shoes but struggles to tie them. | Needs to handle small strings and perform fine movements |
| Likes to "cheer" when she drinks water but always squeezes all the water out while holding a water bottle. The water also spills out when drinking | Needs stable water bottle with mouth piece. |
| Brushes her hair using the wrong side of the comb. | Needs a comb that will allow for combing on the other side of the comb |
| Wears her backpack around her neck. | Needs a backpack can easily place on her back. |

Fig. 5. Interpretation of Need-Knower's Needs

### *B. Hierarchical list of primary and secondary customer needs:*

**Needs support with technology**

- Buttons on devices need to be accessible for her hands
- Needs a stable and responsive device
- Needs help with swiping on the iPad when interacting with her entire hand

**Fine, intricate hand/finger manipulation**

- Needs to put force and make precise movements for washing objects
- Needs to zipper that allows her to unzip clothing
- Needs seat belt for unbuckling and dismantling
- Needs to handle small strings and perform fine movements
- Needs a comb that will allow for combing on the other side
- Needs to mix colored games, cards, etc.
- Needs support reaching her back teeth when brushing her teeth

**Needs support grasping, pulling, etc.**

- Needs grasp control and force application
- Needs stable water bottle with mouth piece
- Needs utensils that can effectively hold and handle food
- Needs grasps to be able to hold things in place
- Needs objects that are very stable with force application

**Needs help packing and unpacking games, material, objects**
**Needs wearables that can be placed and put on well and appropriately**
**Needs sturdy material for bowls, objects, etc.**

### *C. Brainstorming and solution generation*

Refer to Fig. 6

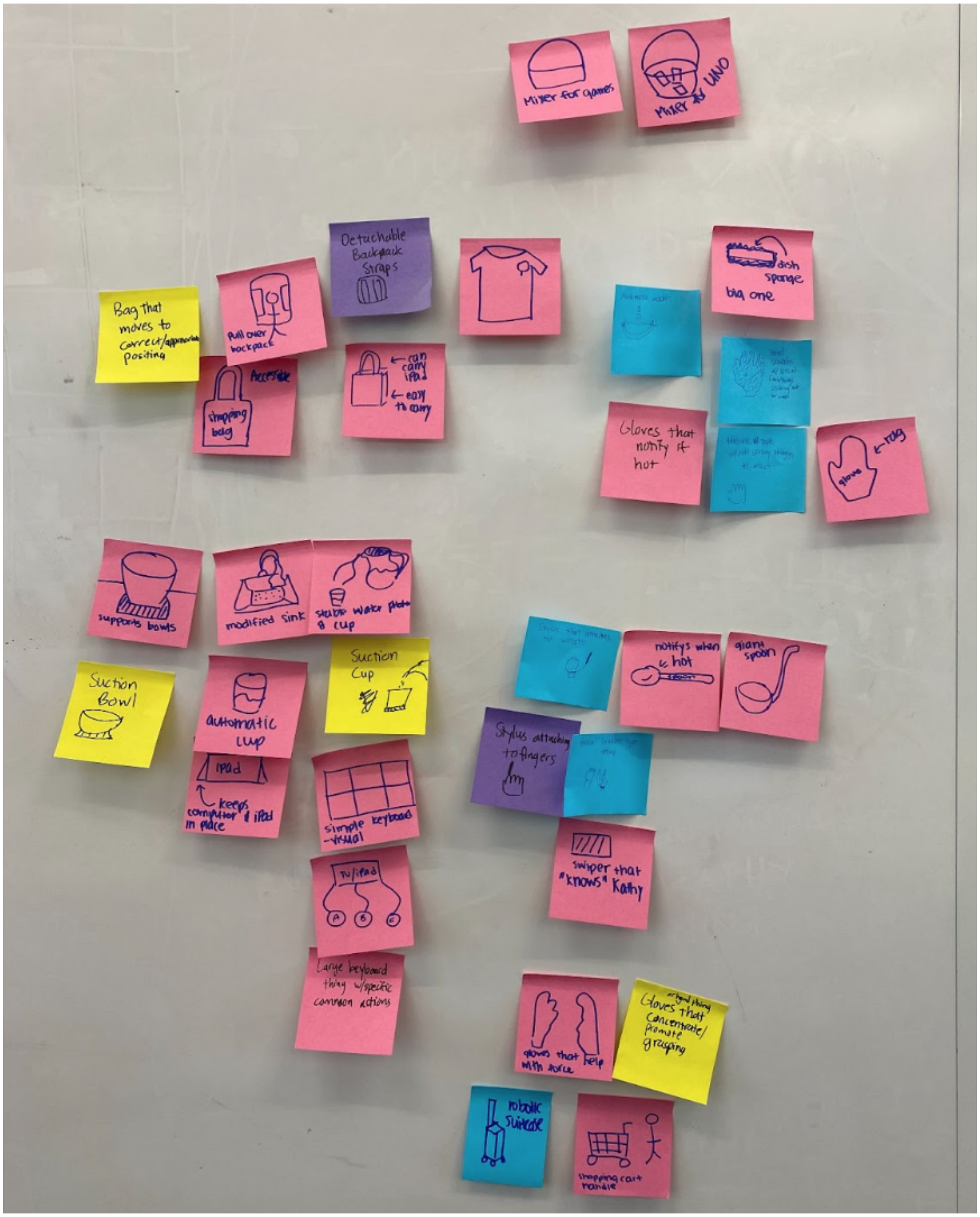


Fig. 6. Brainstorming

## *D. Converging on a single idea*

Refer to Fig. 7

| | Impact x3 | Cost x1.5 | Feasibility x2 | Personal Preference (Likeability) x2.5 | Commercial Ability x1 | Totals | Totals Avg |
|---|---|---|---|---|---|---|---|
| Stable water pitcher and cup | 4 | 1 | 5 | 5 | 0 | 36 | 31.75 |
| | 3 | 3 | 3 | 2 | 3 | 27.5 | |
| Automatic object/food washer | 4 | 3 | 3 | 5 | 0 | 35 | 32.875 |
| | 4 | 2 | 2 | 3.5 | 3 | 30.75 | |
| Simple visual keyboard for common actions | 4 | 3 | 3 | 5 | 0 | 35 | 35.625 |
| | 5 | 2.5 | 3.5 | 3 | 3 | 36.25 | |
| Suction bowl | 4 | 2 | 4 | 5 | 0 | 35.5 | 35 |
| | 3.5 | 4 | 4 | 3 | 2.5 | 34.5 | |
| Spoon/Utensil to notify when hot | 4 | 2 | 4 | 5 | 0 | 35.5 | 36 |
| | 4 | 4 | 4 | 3 | 3 | 36.5 | |

Fig. 7. Weighted matrix

### Final Idea:

After converging on a handful of concepts with all members having a clear understanding of our user's needs, we determined that our winning concept is a smart spoon. This smart spoon notifies users when their food is hot and is shaped to meet the user's needs. All team members agreed on the impact and feasibility of this idea but also found this idea exciting enough to work with. In addition, our selected product concept would meet critical need-knower needs.

### *E. Finite State Machine Diagram*

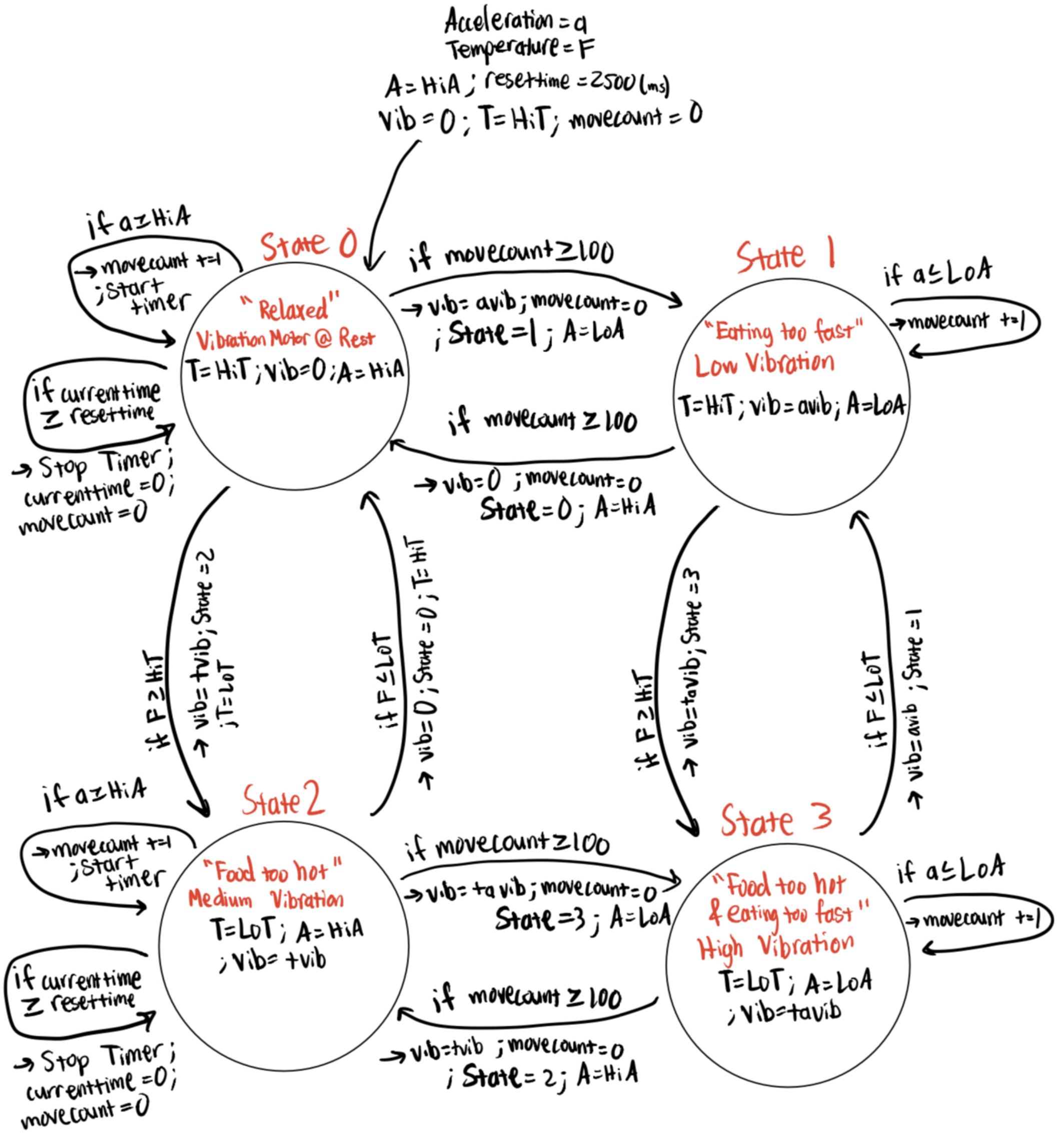


Fig. 8. Finite State Diagram of the device

### *F. Code*

```
// Code for utensil tracking eating speed and utensil temperature and
// notifies user if they are eating too fast or if the utensil is too hot.

// libraries to include
#include <Wire.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_ADXL343.h>
#include <Adafruit_ADT7410.h>
#include <Timer.h>

// Define pins
```

```
#define ADXL343_SCK 13
#define ADXL343_MISO 12
#define ADXL343_MOSI 11
#define ADXL343_CS 10
#define TEMP A3
#define VMPWM 5

// Define variables ------------------------------------------------------------
int AVT = 0; // analog voltage temperature
int C = 0; // temperature in celsius
int F = 0; // temperature in fahrenheit
float a_x = 0; // x-component of acceleration
float a_y = 0; // y-component of acceleration
float a_z = 0; // z-component of acceleration
int HiA = 6; // high acceleration threshold
int LoA = 1; // low acceleration threshold
int HiT = 90; // high temperature threshold for utilizing hysteresis
int LoT = 80; // low temperature threshold for utilizing hysteresis
int State = 0; // initial state variable
int tvib = 125; // pwm value for temperature vibration
int avib = 100; // pwm value for acceleration vibration
int tavib = 200; // pwm value for both temperature and accleration vibration
int movecount = 0; //
int movecountthresh = 80; // threshold for movecount
int resettime = 2500; // amount of time to reset movecount in milliseconds
String TempStatus = "OK!"; // initializing temperature status message
String MoveStatus = "OK!"; // initializing acceleration status message
String VibStatus = "OFF"; // initializing vibration status message
float currenttime = 0; // initializing time keeping variable

// Create the ADXL343 accelerometer sensor object
Adafruit_ADXL343 accel = Adafruit_ADXL343(12345);
// Creating Timer object
Timer timer;

// Function Definition ---------------------------------------------------------

float getAccel() { // Ripping acceleration outputs from sensor and calculating

  /* Get a new sensor event */
  sensors_event_t event;
  accel.getEvent(&event);

  // assign acceleration variables
  a_x = event.acceleration.x;
  a_y = event.acceleration.y;
  a_z = event.acceleration.z;

  /* Display the results (acceleration is measured in m/s^2) */
  //  Serial.print("X: \t"); Serial.print(a_x); Serial.print("\t");
```

```
  //  Serial.print("Y: \t"); Serial.print(a_y); Serial.print("\t");
  //  Serial.print("Z: \t"); Serial.print(a_z); Serial.print("\t");
  //  Serial.println("m/s^2 ");

  // calculate the norm
  float a_x2 = pow(abs(a_x), 2);
  float a_y2 = pow(abs(a_y), 2);
  float a_z2 = pow(abs(a_z), 2);
  float a = sqrt(a_x2 + a_y2 + a_z2);
  //  Serial.println(a_x2); Serial.println(a_y2); Serial.println(a_z2);
  //  Serial.println(a);

  return a;
}


void temp() { // Checking the temperature from the sensor and calculating Celsi
 AVT = (analogRead(TEMP)) * (3.22265625);
 C = (AVT-500)*0.1; // Celsius temp
 F = (C*1.8)+32; // fahrenheit temp
}

void tempaccel() { // state machine for acceleration and temperature
  switch (State) {
    case 0 : {//
      float  a = abs(getAccel()-9.8);
      if (a >= HiA) { // stepping for movecount and starting timer
        movecount += 1;
        timer.start();
      }
      if (timer.state() == RUNNING) { // if timer is running, check time
        currenttime = timer.read();
        if (currenttime >= resettime) { // if 2.5 seconds has passed since last
          timer.stop();
          currenttime = 0;
          movecount = 0;
        }
      }
      if (movecount >= movecountthresh) { // If movecount is greater than 100,
        State = 1;
        MoveStatus = "Too Fast!";
        analogWrite(VMPWM, avib);
        VibStatus = "VIBRATING";
        movecount = 0;
      }
      if (F >= HiT) { // If temp too high, move to too hot state
        State = 2;
        TempStatus = "Too Hot!";
        analogWrite(VMPWM, tvib);
        VibStatus = "VIBRATING";
```

```
      }
    }break;
    case 1 : {// State where eating too fast
      float  a = abs(getAccel()-9.8);
      if (a <= LoA) {
        movecount += 1;
      }
      if (movecount >= movecountthresh) {
        State = 0;
        MoveStatus = "OK!";
        analogWrite(VMPWM, 0);
        VibStatus = "OFF";
        movecount = 0;
      }
      if (F >= HiT) { // if temp becomes too hot, move into state where too fas
        State = 3;
        TempStatus = "Too Hot!";
        analogWrite(VMPWM, tavib);
        VibStatus = "VIBRATING";
      }

    }break;
    case 2 :{ // State where food is too hot
      float  a = abs(getAccel()-9.8);
//      analogWrite(VMPWM, tvib);
      if (F <= LoT) { // if temp gets lower, go back to initial state
        State = 0;
        TempStatus = "OK!";
        analogWrite(VMPWM, 0);
        VibStatus = "OFF";
      }
      if (a >= HiA) { //conditionals for acceleration
        movecount += 1;
        timer.start();
      }
      if (timer.state() == RUNNING) { // if timer is running, check time
        currenttime = timer.read();
        if (currenttime >= resettime) { // if 2.5 seconds has passed since last
          timer.stop();
          currenttime = 0;
          movecount = 0;
        }
      }
      if (movecount >= movecountthresh) { // If movecount is greater than 100,
        State = 3;
        MoveStatus = "Too Fast!";
        analogWrite(VMPWM, tavib);
        VibStatus = "VIBRATING";
        movecount = 0;
      }
```

```
    }break;
    case 3 : {// State where eating too fast and food is too hot
      float  a = abs(getAccel()-9.8);
      if (a <= LoA) { // code to move back to too hot state pt1
        movecount += 1;
      }
      if (movecount >= movecountthresh) { // code to move back to too hot state
        State = 2;
        MoveStatus = "OK!";
        analogWrite(VMPWM, tvib);
        VibStatus = "VIBRATING";
        movecount = 0;
      }

      if (F <= LoT) { // code to move back to too fast state
        State = 1;
        TempStatus = "OK!";
        analogWrite(VMPWM, avib);
        VibStatus = "VIBRATING";
      }
    }break;
  }
}

// Setup ----------------------------------------------------------------------
void setup() {
  // put your setup code here, to run once:
  // Setting pin ins and outs
  pinMode(VMPWM, OUTPUT);

    Serial.begin(115200); // setting the baud rate
//  Serial.begin(300);

// new accel setup
  while (!Serial);
  Serial.println("Accelerometer Test"); Serial.println("");
  /* Initialise the sensor */
  if(!accel.begin())
  {
    /* There was a problem detecting the ADXL343 ... check your connections */
    Serial.println("Ooops, no ADXL343 detected ... Check your wiring!");
    while(1);
  }
  /* Set the range to whatever is appropriate for your project */
  accel.setRange(ADXL343_RANGE_16_G);
  // accel.setRange(ADXL343_RANGE_8_G);
  // accel.setRange(ADXL343_RANGE_4_G);
//    accel.setRange(ADXL343_RANGE_2_G);

  /* Display some basic information on this sensor */
```

```
//   accel.printSensorDetails();
//   displayDataRate();
//   displayRange();
//   Serial.println("");
}
// Main loop ----------------------------------------------------------------
void loop() {
  // put your main code here, to run repeatedly:
  temp();
  float  a = abs(getAccel()-9.8);
  tempaccel();

// printouts for serial monitor/plotter
  // prints out acceleration
  Serial.print("Accel = ");
  Serial.print(a);
  Serial.print("\t");
//   // prints out movecount
  Serial.print("movecount = ");
  Serial.print(movecount);
  Serial.print("\t");
//   // prints out state
  Serial.print("State = ");
  Serial.print(State);
  Serial.print("\t");
  // prints out Fahrenheit Temperature
  Serial.print("Temp (F) = ");   Serial.print(F); Serial.print("\t");
  // prints out food temp status
  Serial.print("Temperature Status = "); Serial.print(TempStatus); Serial.print
  // prints out movement status
  Serial.print("Movement Status = "); Serial.print(MoveStatus); Serial.print("\
  // prints out vibration status
  Serial.print("Vibration Status = "); Serial.print(VibStatus); Serial.print("\
  // prints out timer (starts when movecount steps)
//   Serial.print("Timer: "); Serial.print(currenttime);
  Serial.println();
}
```