ABC - Assistant Baby Crawler

Fig 1

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Problem Statement

There are several toys in the market that assist in developing the intuition in an infant to crawl amongst the plethora of other toys that make up the 111-billion-dollar (about $340 per person in the US) [10] industry. An important for the infant is to develop the intuition of crawling and walking as further down its life it learns to pick important concepts as it grows. This motor skill enables it to fare better in learning newer concepts. Thus, aid in developing this intuition is essential. Amongst these toys, there is a dearth of understanding due to insufficient analysis of the design and development of the toy. Its shortcomings include issues such as not including the infant in its play loop, insufficiently engaging play, static designs, and no feedback system. Several studies in HRI have been performed to study the child robot interaction discipline. These studies take inspiration from various other fields such as cognitive psychology, education, and teaching, robotics, etc. The existing technology in robotics that assists infants in crawling is quite archaic and invasive. It has control over arms and legs much like an exoskeleton. Armed with this knowledge about the importance of intuition in crawling, research in various fields, and human-robot interaction we aim to develop a non-invasive baby crawling assistant robot that will develop the intuition in an infant and motivate it to quickly learn the concept.

Literature Review

Most infants start crawling when they are around six months old, indicating they are stepping into the first important motor skill development stage at an early age. Current researches have certified that crawling is a vital skill that is connected to development far beyond mobility. Some studies have proved compared to the performance of infant crawlers, non-crawlers showed lower average or performance on selected measures of sensory, motor systems of the body, and general motor skill development(McEwan et al, 1991). Another psychoanalyst, Mahler, also states that the onset of voluntary locomotion represents the “psychological birth” of the human infant(Mahler et al., 1975), indicating the relation between locomotor experience and psychological development.

As our first step is to study the motivation of movement, we found research that mentions strongly motivated infants had earlier onsets for motor skills than weakly motivated infants(Atun-Einy et al, 2013). And based on our further observation and research on infant crawlers, we found besides internal stimuli such as infants’ activity level or activity preference, external stimuli could also be a source of motivation, like grabbing things to explore is highly motivating for infants! Thus, we are determined to explore additional external motivations that could elicit infants’ movement in their early stages and try to help assist infants in crawling in the family environment.

To determine the interaction between childs and robotic toys, we also conducted some research on possible games that can be designed in our robot. There are some projects that show that robotic toys can become social mediators, encouraging children with special needs to discover a range of play styles, from solitary to collaborative play (Robins et al., 2008). The objects in this study, children, are generally older than our user group. This paper still provides many insights into making the play as informative as possible when designing our robot. It also classifies the level of collaboration needed with the human for every type of play/skill up, like turn taking, pushing, fetch, hide and seek etc. and determines the level of intuition developed with interest in the play, which provide a solid research base for HRI design in creating a practical robot assistant that improve infant’s body development.

We also get plenty of insights from class discussion and text books we use. We plan to design social cues like minimal motion and movement, as well as intuitive light and sound to keep the baby focused on the robotic toy and make movement with it.

Design Research Methods

We conducted primary research, such as observations and interviews to explore the motivation of infants crawling in the family environment. Based on the Covid-19, we couldn’t make an appointment for an in-person observation, instead, we watched first-hand videos since many parents would love to record every memorable moment as babies are growing up. And also, we found parents doing interviews, in order to gather more information on how they motivate their babies to crawl and how babies would react.

We recruited 5 participants(babies and their parents) to conduct our first-round interviews. This would be the proper amount because research suggests that a good baseline is to start with five and run as many small tests as you could(Neilson, 2012). Two of the participants are located in the U.S and others are overseas.

During the interview, we record the videos via zoom and later translate the videos into text version content. After finishing the interview, we had 5 interview text version results and several pictures/videos they sent to us for elaboration of the actual environment. We coded the text and concluded our findings as follows.

Design Research Findings

Affordances in an object make our lives easier. These affordances are subtle hints and clues that are built into the object that tell us about its use. It is a powerful tool to explain a lot of functionality without scanning manuals of design documents. Research into the various play settings of infant rooms provided us insights into the affordances that can be built into ABC. A play pen is typically filled with various toys at close proximity from the infant. The infant is then free to pick anything that interests it and play with it. As per our interviews, the success of a toy depends on parameters like shape, colour, brightness and noise. These affordances are understood by an infant due to proximity. ABC will have similar design affordances built into it so that there is maximum success of play. The challenge then becomes making ABC strand out of the crowd. This is achieved by adding several layers of play into the robot so that the infant doesn't lose interest as the toy behaves differently every time it senses a loss in focus.

There are a host of different plays with their successes and scenarios mapped out by B. Robins, E. Ferrari and K. Dautenhahn, (2008)[2] . This data provides us with a plethora of information about the types of plays ABC needs to house for the best results. We want to stimulate sensory and motor aspects in the infant so that it attempts crawling on its own. BAsed on the research data available, turn taking is suggested as an excellent play scenario for developing the desired skills. Hence ABC will need to sustain a turn taking mechanism with the infant in order to teach crawling. The idea here is to lead with the robot and let the infant follow at first. The level of success at every play can be tracked using length of interaction and amount of motion by the infant.

Simple facial characteristics in robots such as hair length can invoke strong gendered biases and perceptions in users[Eyssel, F. A., & Hegel, F. (2012)]. These subtle clues can lead users to reflect on their p[ersonal biases and project them onto a robot thereby pigeon holing them into believing the capabilities of the robot. This is an issue in two ways. A robot's characteristics only depend on the type of electronics and codes it has been programmed with and not its appearance. This is therefore misleading the user into making imaginary use cases that the robot is capable of. This would also pose an ethical challenge as the robot would be further reinforcing the misguided notion of gender in robots. Secondly, there is an added notion of frustration about objects that do not behave as they are perceived. In our use case the infant is at an impressionable age while still trying to figure out many aspects of life. At this juncture introducing design themes that have gendered notions to them can lead to learning certain traits subconsciously. To avoid this we have chosen a generic robot toy like design that is impossible to genderize and rather focuses on the learning of goals. Therefore we do not use pronouns with ABC rather the use “it”.

Infants at their early stage react strongly to movement and encouraging or discouraging noise tones rather than parts of speech. These non verbal cues are a cornerstone in the learning process of the infant’s early years. We plan to adapt this into ABC through microphones and speakers. ABC needs to be equipped with pleasing and soothing tones sampled from adult voices. These voices could be pre recorded or computer generated. Every attempt made by ABC to engage with the infant can be aided by these tones. This improves interaction with the infant as it treats it as a familiar object and could trigger its last memory of the attempt made at crawling over several iterations.

A secondary non verbal cue is the aspect of getting the infant to make an attempt at crawling. Crawling begins with the infant trying to bounce to its feet and landing at its hands. A gentle bouncing/bobbing motion could trigger the infant into following this action. Over a period of time the infant's motor muscles strengthen and it learns to get up slowly.

iCub[1] is a popular robot that was aimed as a testbed for AI research. It is a human-like robot that mimics a human-like friend of the child. The final robot and its mannerisms trigger an uncanny value feeling in several users as research suggests. The iCub robot has been trained to mimic an infant's crawling. It can therefore be left in a playpen with an infant and over time the infant learns by mimicking iCub thereby learning how to crawl. Its humanoid design affects its use in a real world setting as it invokes unsettling feelings in several human users. Therefore its humanoid design severely restricts its use in the real world. This is an important discovery while planning out the design of ABC. We ruled out humanoid designs with this research

From our research we understand that infants have a spatial awareness and resolution of about 25 centimeters. Research suggests that this falls into the personal space of the user[5]. From the data we gather that a play pen is an enclosed space where the infant spends a considerable amount of time familiarizing itself with its surroundings. These toys are designed to invoke/ challenge its current perception of the world and adapt.In this setting everything within 25 centimeters of the infant is bound to be gazed upon by the infant. Care must also be taken that the infant has short attention spans and is quick to fatigue. Therefore while remaining in personal space ABC must try to maximize the time it can get for interaction, improve learning of the desired task and then understand when to stop so that there isn't too much fatigue. Therefore ABC will try to attempt teaching the baby over sparse periods of time in order to avoid overburdening and/or “programming” the infant with its persistent attempts.

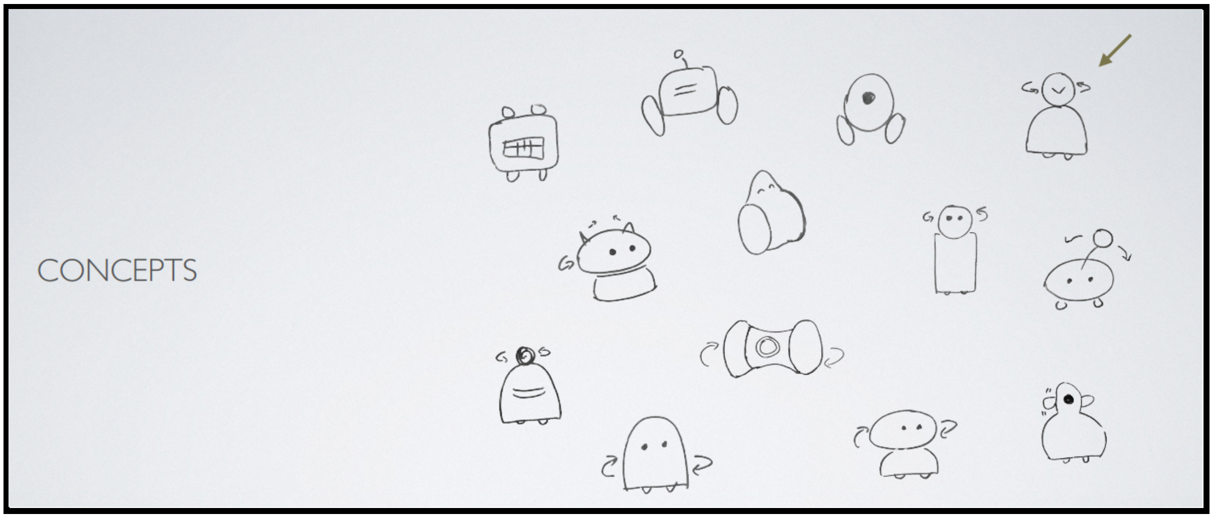

Fig 2: Design concepts of ABC

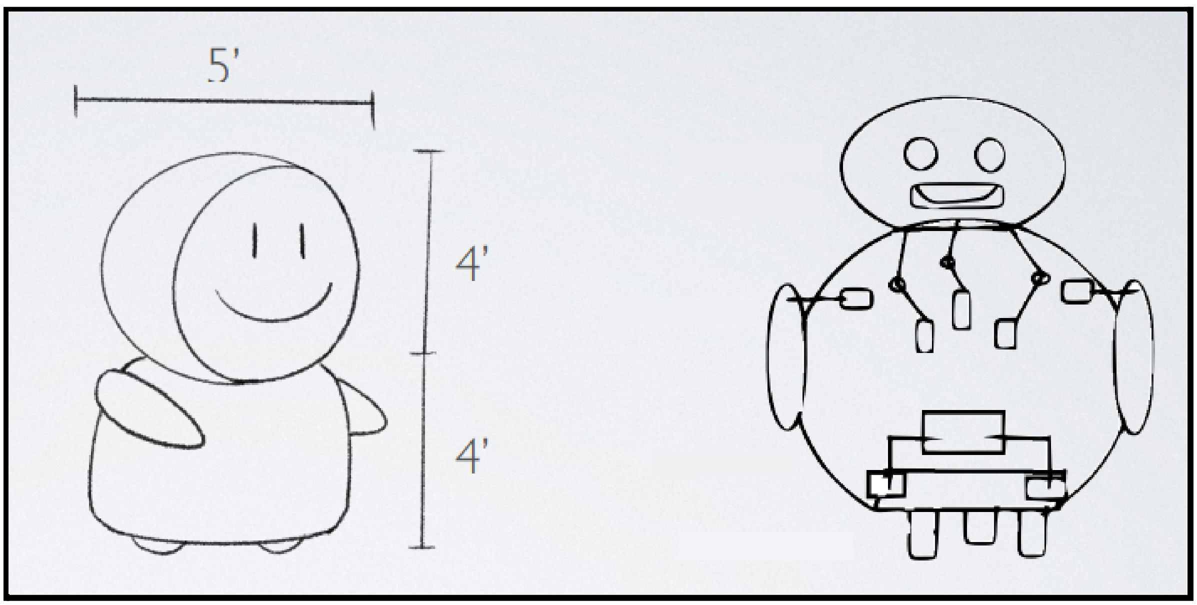

Fig 3: Schematic diagram of ABC

Prototype Design

The ABC prototype has been divided into three abstract layers based on the ideas in our design phase. The robot's plan of action at every stage hinges upon the result of these three phases.

First is the movement or locomotion capability. ABC is a semi autonomous robot capable of movement and positioning itself. This is facilitated with the help of two motor controlled wheels and one castor wheel for balance.

Second layer is the search layer. ABC must be capable of searching for the infant in the play pen. Here we have made an assumption based on our research data into play pens, that an infant is the largest object in the play pen. ABC is the size of an average toy in a general playpen. Hence to search the subject ABC needs to plan its motion at every juncture. This is done by searching its surroundings. To facilitate search we use a servo attached to the head of ABC. By default ABC looks to its left first then right. The reward is getting closer to the infant.

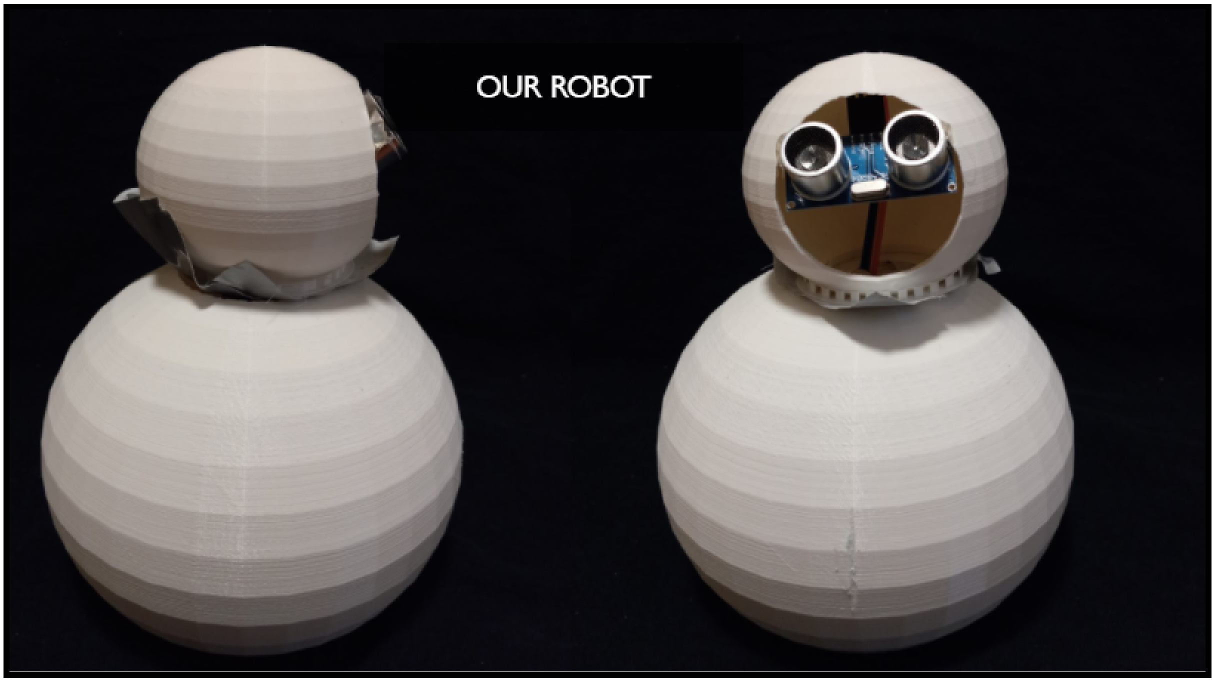

Fig 4: Final ABC concept

Third layer is gaze tracking. We know from our design studies that 25 cms is the furthest an infant can distinguish. We have set ABC to get close to the infant but remain within 15-25 cms away. This is facilitated by the ultrasonic sensors attached on its head. The ultrasonic sensors are focused pointing upward since we know that the infant is the largest object in the room. This would avoid ABC detecting larger toys and mistaking it for an infant.

ABC is powered by 4 AA type batteries. We tested several iterations of powering via one 9v battery and through the arduino cable. HOwever we found that the 9v battery and the secondary power source/arduino does not provide sufficient power for full range of motion. Here the issue arises due to current while the potential difference is sufficient in every case, current values vary wildly.

Final ABC design has been conceptualized over the course of design and prototype considerations. We focused on a toy like robot to satisfy all constraints in the research. ABC is a moveable robot that has two visible moving parts that perform synchronously based on inputs from the arduino. This is in line with the minimalistic approach we wanted to reflect from our robot.

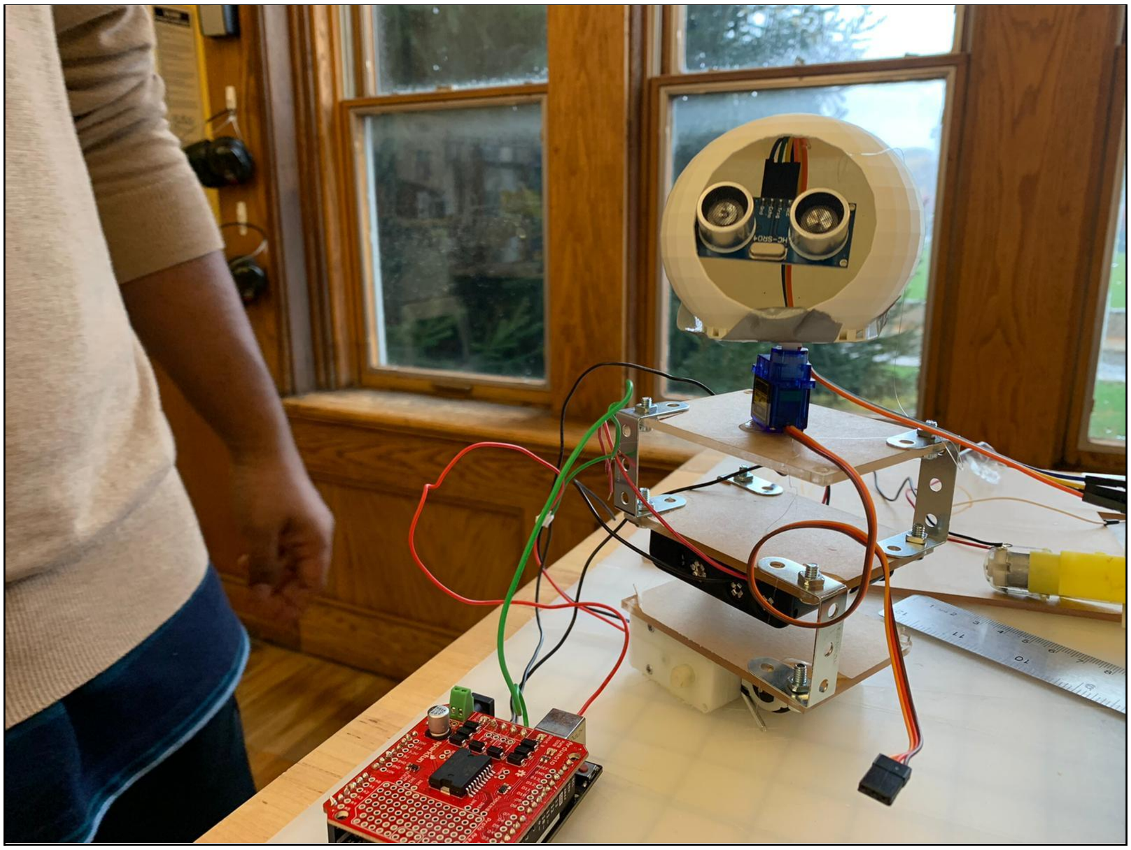

Fig 5: Internal design

In a schematic diagram [Fig 3] we have hashed the future scope and components/ capabilities of ABC. This includes adding movable arms, a soft body, led lights and slow bobbing/bouncing motion.

User Evaluation

The finalized concept of ABC was field tested. We collected feedback from several users during the design and deployment of the robot.

The concept design of ABC was 3d printed. This concept design was arranged in the final planned design of ABC as it would look in final form. Photographs of this design from various angles were shared with users to gather insights. We wanted to understand whether the design made people uncomfortable or if ABC provided un-intended affordances about its capabilities. Six of the participants liked the design concept while remaining remained neutral. Six participants were able to judge that it is a toy robot with two independently moving parts of head and torso. The design did not trigger an uncomfortable sensation or uncanny feeling from any of the participants.

Working prototype of the robot was demonstrated to twelve peers. Some of the demo was done in person however the majority of the demonstration was done over video footage of ABC in action. The age group of this demographic ranged from 19 to 35. We asked questions like how they felt about the robot? What is the projected capability of the robot and would they be interested in its development. An overwhelming majority showed interest in the robot during the demo. They were curious about its functionality. This was not a wizard of oz experiment. We demonstrated the final working prototype in its complete functionality. ABC invoked positive emotional response from all users. One of the users who has experience with robotics was able to correctly deduce the functionalities however most of them found out the functionalities as ABC demonstrated them. Seven of the users were interred in the prototype and were eager to know about next iterations and the plan for this robot.

ABC was demonstrated amongst fellow HRI student peers after explaining the concept and rationale behind this prototype. It received an overwhelmingly positive response. People appreciated the design and the final prototype.

Reflection:

This project taught us multiple aspects of robot design and incorporating HRI into a robot. Initial jitters in finalizing the design of ABC. The iterative approach in narrowing down our broad design vision based on our knowledge of robots and finalizing a non gendered, toy like robot was fruitful. We had multiple designs of ABC all of which were fairly novel. We eliminated the designs that didn't solve all the issues presented in design research and narrowed down to the final concept design. This was well thought, planned and executed. In future we would spend additional effort in determining the shape of the robot particularly the type of shapes that are more intuitive and provide additional affordances.

Prototype development phase was particularly challenging due to multiple aspects. Once the concept was finalized we 3-D printed the robot shell in order to get evaluation from peers about possible additions to be made. This left little room for electrical components that could be added to the robot and left little margin for error. This also meant that the robot could not be debugged once deployed. This will be in our future considerations of the robot.

In terms of functionalities of ABC we have provided necessary but not sufficient components. In lieu of its design, ABC needs LED sensors that show its “planning” and next phase of action. This adds an additional layer of trust amongst its users(parents). An important aspect of the design consideration was sound/pleasing tones to help soothe the infant. This needs speakers in the robot. To improve gaze tracking we could swap the ultrasonic sensors with a depth perceiving camera. This could track eye movements via computer vision and provide better feedback for its analysis. A final reflection in the prototype design phase was the unnecessary noise introduced by servos and motors. This will need to be dampened in future iterations where possible.

The human robot interaction aspect of the robot has been planned in great detail however, this has not been tested with the end user i.e. infants. In future we would like to further refine the robot by studying its effects and success/failure. We would plan out short durations where the robot directly interacts with ABC during its play time and observe the reaction. We would like to map parameters such as length of interaction, success of interaction,best spatial fit in the infant’s surroundings and many more.

Finally ABC points to several ethical conundrums[Riek, Laurel and Howard, Don, (April 4, 2014)]. Formative years of a child are the most impressionable ages. These experiences shape the child;s personality and help determine future successes. This is why ABC is planned such that it tries its best to help the infant in every possible way. However this also leaves questions like what could be the long term effects of every action of ABC during the infant;s interactions?, could the robot somehow mould the personalities of infants that play with it in a certain way against the infants that didn't have any interaction with the robot.

We discussed the turn taking aspect of the robot that has been suggested as an excellent way to help stimulate sensory motor play. This begs to question as suggested in [],could ABC be used to influence infants with certain behaviours? The tradeoff between submissive and dominating nature of ABC needs to be evaluated[Sparrow, R. (2016)].

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Appendices

Questions during interviews:

Questions we could ask(within 40 mins):
1.Do you remember when did your baby start to crawl?
○6 months old? Earlier or later?
○With or without parents’ help?
2.How often did your baby usually practice crawling on a normal day? (Activity Level)
○<3 times?
○3-10 times?
○> 10 times?
3.How long for each time? (Normally would be the robot interaction cycle)
○30 mins? More or less?
4.What kind of environment did you prepare for your baby? Could you describe it?
○In a Playpen?
○On a soft floor?
5. What would you usually do to help your baby practice crawling?
○Would it make your baby feel happy?
6.Is there some way, like playing toys or games with him/her, that would be useful to motivate crawling? (which motivation works best)
○If sounds:
■What kind of sounds would you make? Could you describe it?
■How would your baby react?
■What kind of sounds did your baby like most?
○If crawling toys:
■Do you still keep his/her favorite crawling toy? Could you please show us?
■What kind of toy is that? Can it move? Make sounds? The toy’s size?
■How did your baby play with it?
○If the baby won’t need to be motivated by others:
■Which direction would they usually crawl towards? What’s there?

7. Were you always staying with your baby when she/he was crawling?
○If yes:
■Do you have any concerns if your baby is playing with a robot?
○If not:
■Do you feel safe or trust the robot when it is playing with the baby?
8. Do you still keep some videos you recorded when your baby was crawling?
○Could you show some to us? (Would be really helpful when we thinking about the robot design)

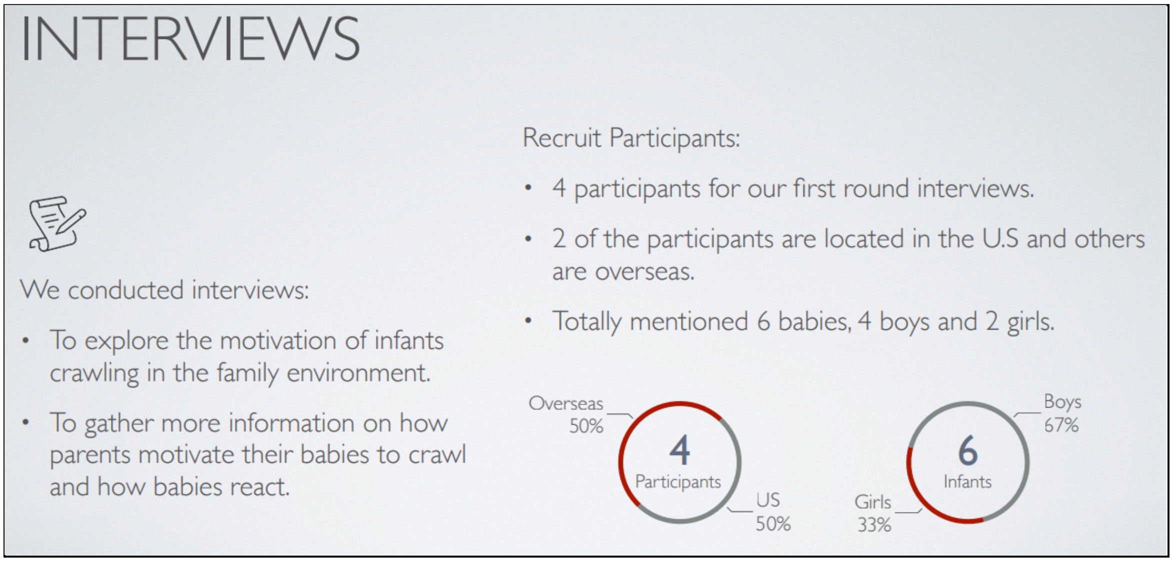

Fig 6: Interview insights brief

The drive link to interviews:
https://drive.google.com/drive/folders/1dvydoRd7nH6EKNzUTw3JsKj2ik7C_3tV?usp=sharing
We have protected this link from access due after checking with our participants. If access is needed please reach us.

Context of use:

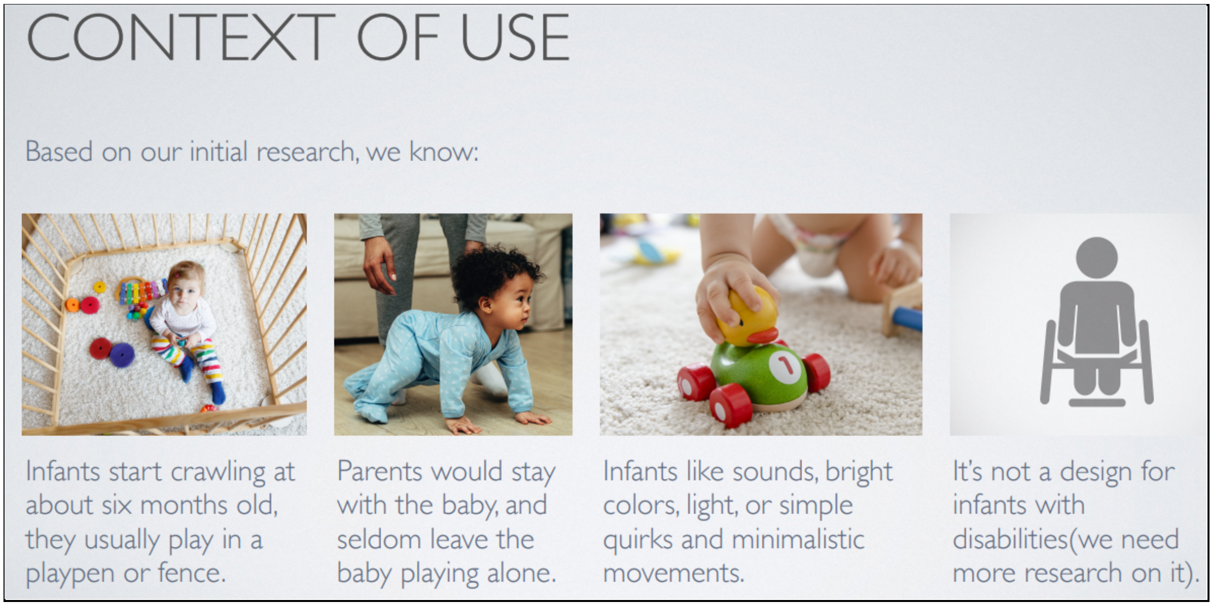

Fig 7: Context(s) of use

Photos:

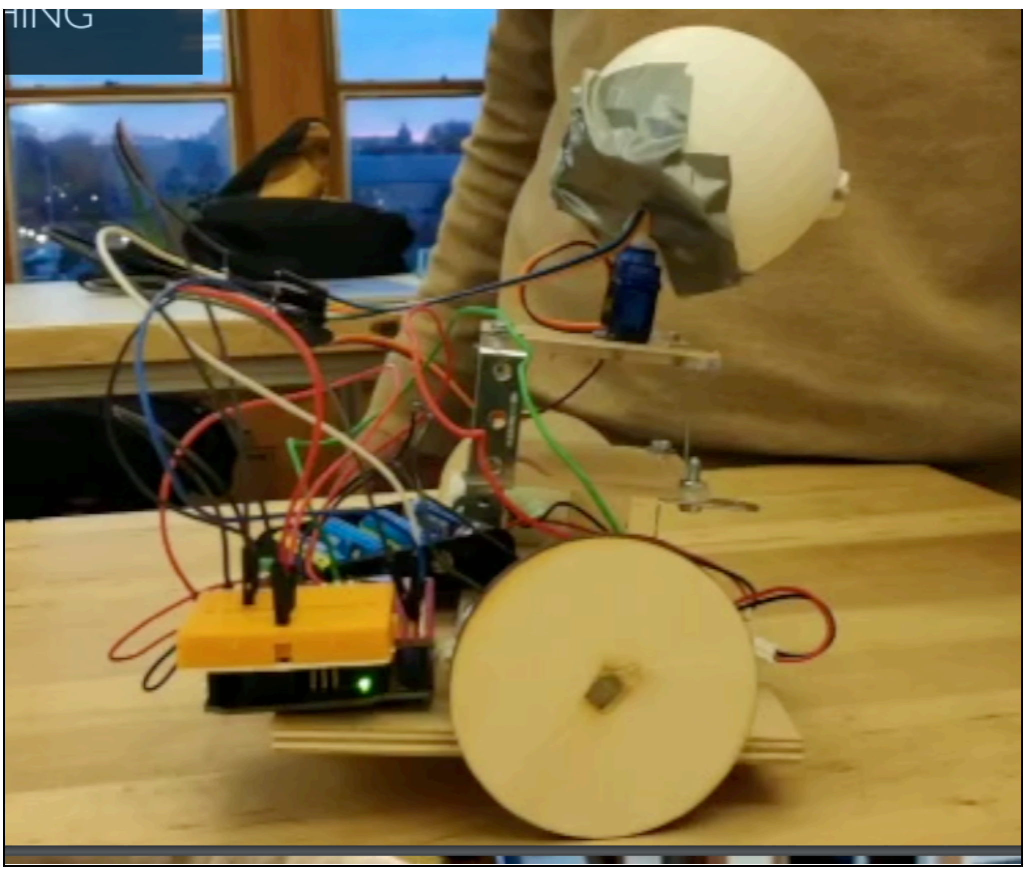

Fig 8: Side view of ABC v1.

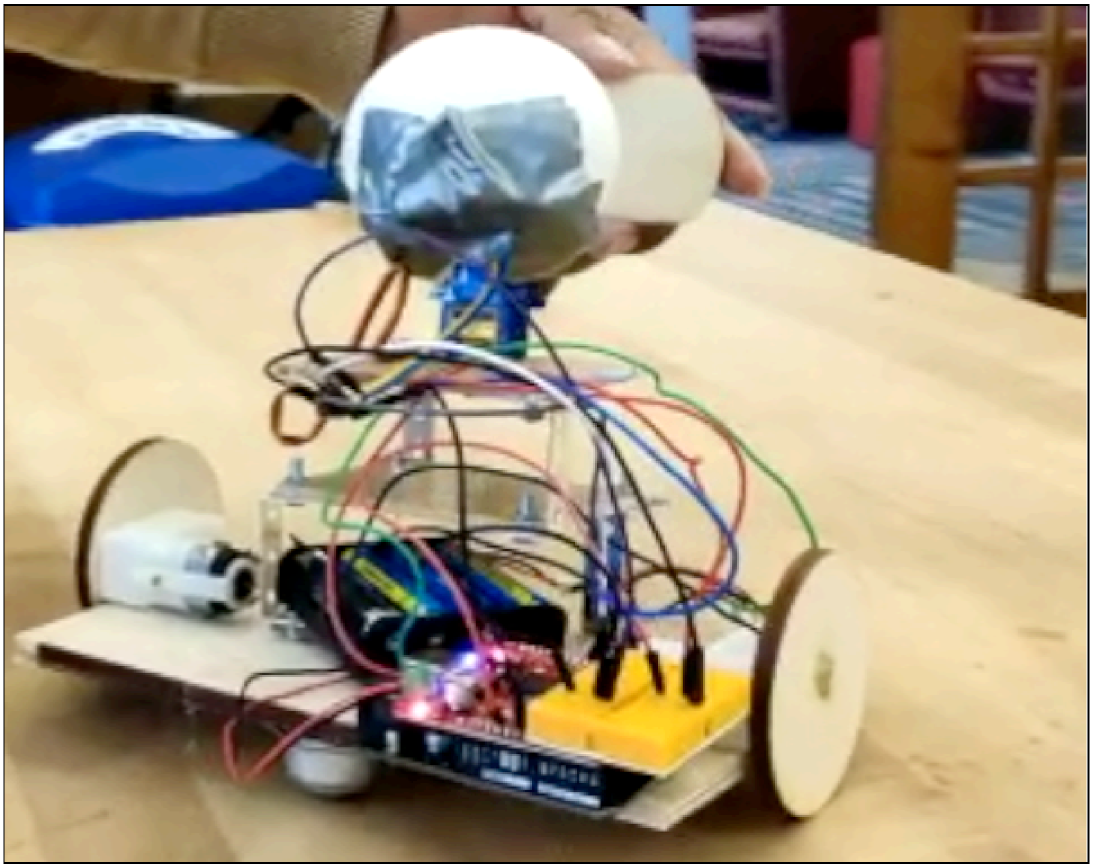

Fig 9 ABC searching

Presentation:

https://iu.instructure.com/courses/1999565/assignments/12572725

Arduino code [8] [9]:

#Search algorithm has been implemented by us . Motor movement and distance tracking has been understood from references.

```
int prev_distance=-1;

#define FORWARD  0
#define REVERSE 1
#define MOTOR_A 0
#define MOTOR_B 1
#define DIRA 2 // Direction control for motor A
#define PWMA 3  // PWM control (speed) for motor A
#define DIRB 4 // Direction control for motor B
#define PWMB 11 // PWM control (speed) for motor B
#define echoPin 7 // attach pin D2 Arduino to pin Echo
#define trigPin 8 //attach pin D3 Arduino to pin Trig
int dir = 1;
```

```
unsigned long timestamp;
long duration;
int distance;
#include <Servo.h>
int servo_value=90;
Servo myservo;
int pos = 0;

void setup() {
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  Serial.begin(9600);
  myservo.attach(5);
  myservo.write(servo_value);
  setupArdumoto();
  timestamp = millis();
}

void driveArdumoto(byte motor, byte dir, byte spd){

 if (motor == MOTOR_A){

   digitalWrite(DIRA, dir);
   analogWrite(PWMA, spd);
} else if (motor == MOTOR_B){
    digitalWrite(DIRB, dir);
    analogWrite(PWMB, spd);}
}

// stopArdumoto makes a motor stop

void stopArdumoto(byte motor){

 driveArdumoto(motor, 0, 0);
}

void setupArdumoto(){

 pinMode(PWMA, OUTPUT);
 pinMode(PWMB, OUTPUT);
 pinMode(DIRA, OUTPUT);
 pinMode(DIRB, OUTPUT);
 digitalWrite(PWMA, LOW);
 digitalWrite(PWMB, LOW);
 digitalWrite(DIRA, LOW);
digitalWrite(DIRB, LOW);
}
```

```
void loop() {

     digitalWrite(trigPin, LOW);
  delay(10);
 digitalWrite(trigPin, HIGH);
 delayMicroseconds(10);
 digitalWrite(trigPin, LOW);
 duration = pulseIn(echoPin, HIGH);

 // Calculating the distance
distance = duration * 0.034 / 2;
  Serial.print("Distance: ");
Serial.println(distance);
int d1=distance;
 int d2=d1;
if (distance==0){ // added to avoid haywire motion during loose connection}

else if(distance<=5){
    move_back();
    Serial.print("Moving back ");
    Serial.println(distance);
} else if(distance >=20 and distance <50){
     move_forward();
    Serial.print("Moving forward ");
Serial.println(distance)
 }else if(distance >=50){//search
    servo_value=90;
   servo_value=move_servo_back(-40,servo_value,distance);
   d1=return_distance();
 servo_value=move_servo(80,servo_value,distance);
d2=return_distance();
Serial.println(d1,d2);
   if(d1>d2){
      move_right();
      Serial.print("Moving right ");
      Serial.println(d2);
      Serial.print(" ");
      Serial.println(servo_value);
      move_forward();
} else if(d2>d1){
     move_left();
      Serial.print("Moving left ");
      Serial.println(d1);
      Serial.print(" ");
      Serial.println(servo_value);
```

```
      move_forward();}
   else{move_forward();}
}

 int return_distance(){
    digitalWrite(trigPin, LOW);
    //delayMicroseconds(2);
    delay(10);
    digitalWrite(trigPin, HIGH);
    delayMicroseconds(10);
    digitalWrite(trigPin, LOW);
    duration = pulseIn(echoPin, HIGH);
    distance = duration * 0.034 / 2;
    return distance;
}

int move_servo(int deg,int servo_value,int distance){
     int i =servo_value;
     for (i=servo_value;i<=(servo_value+deg);i=i+5){
           myservo.write(i);
           delay(100);
}servo_value = i-5;
return servo_value;
}

int move_servo_back(int deg,int servo_value,int distance){
    int i =servo_value;
     for (i=servo_value;i>=(servo_value+deg);i=i-5){
           myservo.write(i);
           delay(100); }
      servo_value = i+5;
      return servo_value;
}

void move_head(int deg){
    int i,j;
    if(deg>0){
            for (pos = 90; pos <= 90+deg; pos += 2) {
                      myservo.write(pos);
                      delay(15);
             }
       } else if(deg<0){
               for (pos = 90; pos <= 90+deg; pos -= 2) {
                     myservo.write(pos);
                     delay(15);
```

```
        }
    }
}

void pause_for_few(){
  delay(1000);
  stopArdumoto(MOTOR_A);
   stopArdumoto(MOTOR_B);
  delay(5);
}

void move_back(){
driveArdumoto(MOTOR_A, REVERSE, 255);
driveArdumoto(MOTOR_B, REVERSE, 255);
pause_for_few();
}

void move_right(){
  driveArdumoto(MOTOR_B, REVERSE, 255);
  driveArdumoto(MOTOR_A, FORWARD, 255);
  pause_for_few();
}

void move_left(){
  driveArdumoto(MOTOR_B, FORWARD, 255);
  driveArdumoto(MOTOR_A, REVERSE, 255);
  pause_for_few();
}

void move_forward(){
  driveArdumoto(MOTOR_B, FORWARD, 255);
  driveArdumoto(MOTOR_A, FORWARD, 255);
  pause_for_few();
}
```