Nourishing the Future: Using Smart Trays to Foster Sustainable Food Choices Among Primary School Children

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The smart tray aims to raise awareness about the environmental impact of meat consumption among children aged 4-14 in primary school canteens. Utilizing a streak system, smileys, and text display, the tray provides engaging feedback to inform and motivate children about sustainable food choices. The study evaluated the smart tray with 20 parents, revealing overall positive reception but concerns about potential obsessive behavior or eating disorders. Suggested improvements included age-inclusive design and more detailed feedback. Ethical issues, such as targeted advertising and hunger suppression, were addressed by proposing human supervision, nutritional thresholds, and non-profit affiliations. Although the current study faced limitations in user feedback and iterative prototyping, the smart tray presents a promising tool for promoting sustainable habits in children, contributing to the fight against climate change. Further development, testing, and functionality improvements are required before successful implementation in school canteens.

Additional Key Words and Phrases: LowFi, prototype, sustainability, meat consumption, food choices

1 INTRODUCTION

The need for sustainable consumption patterns has become increasingly pressing, as environmental pollution is affecting people and ecosystems all over the world. It is the leading environmental cause of illness and mortality [27] and leads to catastrophic consequences for the earth like natural disasters and decreasing biodiversity [3].

About 25% of all greenhouse gas emissions can be attributed to agriculture and consumption, making diet change an effective way to decrease both personal and global carbon footprints. A global decrease in meat consumption could cut the cost of tackling climate change in half [4].

Despite growing awareness of the need to consume more sustainably, accurately assessing the environmental impact of our food choices remains a challenge [18]. As a result, many decisions regarding our diet are not optimal, potentially leading to a negative impact on the environment. Unfortunately, these consequences are not directly experienced by the individual, but they can have severe and long-lasting implications for the environment, and ultimately the planet's future.

The group of people most likely to experience these long-term consequences are children, as the effects of climate change become greater the longer we wait. But with this group also lies the most potential to change this future around, as they are most susceptible to learn new behavior and attitudes that lead to unsustainable diets [17].

In this context, we present a solution - a smart tray that empowers children to reflect on the impact of their food choices with regards to the environment. In particular, this tray is aimed at reducing meat consumption, as this is the largest contributor within our diet to environmental pollution [18]. Our approach allows children to reflect and receive feedback on the impact of their dietary choices. The tray gives feedback in the form of a smiley face, motivating messages and streaks, which also doubles as a gamified challenge. These components encourage and reward more sustainable food choices in terms of meat consumption. The tray design was a result of our prototyping process, and it is a useful product that allows for easy integration in school canteens, facilitating scalability.

The innovation of our work lies in its ability to inspire motivation for sustainable consumption in children. Our product is the first smart tray that focuses on the sustainability of the foods placed on top of it. So far, little research has been done involving children and sustainable diets. With our tray, we bring a tangible method to increase awareness of sustainable diets, providing a practical and engaging solution to a pressing problem - empowering the next generation to make more informed and sustainable dietary choices.

To determine if the elements of our tray are truly effective for this purpose, it needs to be evaluated with children. Since this is a vulnerable target group, the product first has to be thoroughly examined to minimize the risks posed. Initial evaluations have been done with parents to gather feedback about the tray and its elements during the prototyping process. With these evaluations, this study aims to answer the following research question: *'Can we make children aware of the environmental impact caused by their meat consumption using feedback and gamification?'*

Our hypothesis is that parents will find the elements of the tray adequate for raising awareness about a sustainable diet among their children. We also expect to gain insight into whether the product's playfulness and design appeal to children so they remain engaged with it over time.

In the rest of this paper, we provide a detailed account of the design process, covering the various elements of the smart tray. We also describe the challenges faced during the various development phases, the rationale behind the design decisions, and the steps we took. The feedback and modifications resulting from the evaluation with the prototype are also described and interpreted. Possible improvements and directions for future work are discussed at the end, these include further user testing, improving tray functionality with automatic food recognition, enhancing feedback messages to educate children about sustainability, and extending the product's capabilities to consider other aspects of a sustainable diet.

2 RELATED WORK

The environment is impacted negatively in many ways through choices made in for example transportation methods [14], fashion [7], and food [4]. Earlier research has shown that people find it difficult to consistently make pro-environmental choices when this means their comfort is at stake [25]. Moreover, research has shown that the public is generally reluctant to eat less meat because of

cultural and social values [18]. However, compared to transportation and fashion, dietary changes are smaller and easier to maintain. Through small dietary changes, it is possible to achieve an "efficient" way of making a positive environmental impact, as food production is a big threat to the environment [11]. Within our diet, meat consumption plays the most influential role in terms of environmental impact [28].

Studies that focused on reducing meat consumption have addressed this issue, finding that a combination of health and environmental messages help to reduce meat consumption and encourage general pro-environmental behavior [28]. Moreover, by influencing decisions through small interventions, also known as "nudging", along by providing additional information, people can be influenced to make more sustainable food choices [1]. For this, intrinsic motivation is crucial, which is motivation that comes inherent satisfaction [9, 21].

Another factor negatively influencing people their decision-making, is the inability to process long-term decisions [20]. This issue can be resolved by making the impact of your decisions immediately visible. Earlier studies have achieved long-term visualization through virtual reality (VR), showing "impact messages" next to items in a grocery shop, informing the user about the product's environmental and/or health impact. These impact messages were shown to increase pro-environmental choices [19]. A similar study in VR that found the same effect allowed users to experience scenarios of climate change in accordance with their food choices. The effect was greater when users could change their food choices and experience the positive effect on the future environment [22]. Similarly, we hope that by encouraging our users to improve on their choices and showing them the reduced impact on the environment, it could also motivate them to keep making better choices.

Another study was done using VR pop-up messages in supermarkets, but this time involving children. They found that information about awareness and environmental impact, like 'palm oil can destroy the rain forest', were only adequately understood by children older than 10 years old. However they did find that when the children understand the information about the impact on the environment, it can positively influence their awareness [24].

There are several studies that have provided real-time information to positively impact awareness through a more similar product to our tray. One of these used a smart plate that measures the nutritional value of the food on it, aiding the user in managing their diabetes [15]. Even though this study focused on nutrition instead of sustainability, it shows the effectiveness of feedback through eating utensils. This study also showed the possibility to recognize the food on the plate using computer vision, which is a useful feature for our tray in the future.

Comparable studies involving trays have been performed as well. One study tried to promote healthy decisions in a school canteen with a smart tray. They found that a simple progression bar showing kcal and nutrition intake was not engaging enough and that the design was not playful enough, especially for young people [8]. Their users expected more fun feedback like colors and rewards after making healthy decisions. Even though our smart tray has a different focus, sustainability instead of health, these are important results to take into account. We believe our tray to be more playful as it incorporates colors and pictures in the design, and through gamification it also offers rewards in the form of a streak. The feedback in the form of smileys and text is also more engaging than progression bars.

Even though playfulness is an important factor and is supported by gamification, studies have found that the general design and implementation of the product can be more important for engagement, so it is important to not forget these aspects [10]. They did find that gamification is still effective for keeping users engaged with the product over a long period of time, which is important for our tray as well since a change in awareness takes more than a few days to develop.

Another tray study, performed in a hospital setting, encouraged slower eating by measuring the weight of the food on the tray and displaying people's eating pace on a smartphone application [16]. They too found that real-time feedback during eating can be helpful, but that this feedback is best when ambient, not interrupting the user. Since our feedback is updated only once, does not change during the meal, and does not include blinking lights or sound, it will not draw the user's attention during eating and is thus ambient.

Our product is the first tray to raise awareness on the topic of sustainability. While it resembles other nutrition-focused trays that give direct feedback about food choices and use gamification, our tray is specifically for children and features playful feedback elements and design.

3 DESIGN

With this project, the intention from the beginning has been to make a positive impact on the environment by helping people make more conscious choices. While considering tangible solutions to achieve this goal, the idea of a smart tray was not the first to come to mind. In this section the process from the first idea until the final design of the product is described.

3.1 Ideation

For people to make environmentally conscious choices, they need to be aware of the impact that their choices have on the environment. As mentioned before, this impact is often not directly visible which makes it hard to discern. Thus, our goal has been to make it visible through a tangible product.

There is a broad range of choices that influence your impact on the environment, like transportation modes, shopping habits, and diet. As it would be very hard to change multiple aspects of your life at once, we thought it most effective to focus on one. Considering that environmental impact can be reduced significantly through diet [11], of which meat consumption contributes the most [28], this was chosen as the focus.

Several products were considered to visualize the impact of meat consumption, such as VR glasses, an artificial house plant that doubles as a lamp, and a crystal ball. From discussing the ideas with acquaintances as potential users, we received mixed feedback. It was not clear how the products could be made useful and integrated into people's daily lives. The target audience for the product was also not immediately evident, what kind of people would be willing

to change their habits and what would motivate them to do so?

Then, inspiration was taken from a research paper about mannequins in fashion stores [23]. Just like mannequins carry fashion, plates carry food. A plate could be a useful tangible product that is naturally integrated into people's daily life and that can give immediate feedback about the food on it.

While considering the target audience that would be most open to receiving feedback about their diet choices, and to behavior change [2], we thought of primary school children. Even though children do not always have an influence on the food served to them at home, there are many schools worldwide in which they get to choose what to eat at school. The plate could be used in primary schools where children get to pick from a buffet or food stalls, which is common in many countries, for example in the US, Japan, and Spain.

With this target audience and context, it is important to consider what types of visualization would work best to communicate the environmental impact of food choices. A simple, engaging, yet easy-to-understand type of feedback are smileys. These could be used to indicate the general sustainability score of their chosen meal. Research has shown that the most effective way to achieve long-term behavior change is by increasing intrinsic motivation [9]. This type of motivation is more effectively enhanced by positive rather than negative feedback [12]. Therefore only smileys with expressions ranging from neutral to happy were used.

3.2 Final concept

The changing feedback from the plate needs to be incorporated with electrical components like displays. It would not be practical to incorporate these into the plate itself, as it comes in direct contact with food and should thus be washable. A base for the plate could be used to display the smiley. For the first sketches of the smart plate, a big smiley was shown on the base with a see-through plate on top, as shown in figure 1.

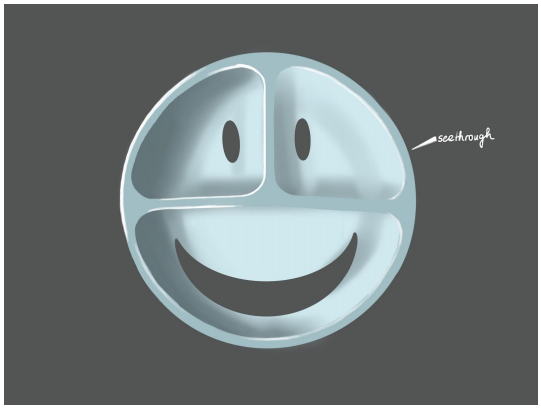

Fig. 1. A design for the intermediate product idea of a plate.

Instead of creating a base that would specifically fit our designed plate, we realized that a base that can fit plates of other shapes and sizes would be more usable. This allows people to continue using the plates they already have, which can differ depending on cultural background and preference. A large base to put a plate on is basically like trays used in canteens for carrying food. When adapted in canteens, the tray could help whole groups of people instead of just individuals. Thus we shifted from the plate design to a smart tray, which could be integrated in school canteens worldwide.

3.2.1 Feedback elements. Having a larger base allows for more types of feedback to be incorporated. The smiley alone provides only basic feedback, as by itself it does not show that the tray gives feedback on meat consumption. Additional information in the form of spoken feedback would not fit in the context because canteens are often already noisy, so we opted for a text box on the tray instead. The text box would display motivational messages, such as compliments for choosing a meat-free meal or suggestions for small adjustments to their meal that would make it more sustainable. However, as mentioned in the related work, it was found that children need to be able to understand the information in the messages for them to become aware of their environmental impact. So the messages do not go into much detail on how meat exactly is unsustainable.

The text box can also be used for personalization as the child can be addressed by their name. This can make them feel valued and also increases their attention to the feedback [26].

We decided to also include an element of gamification in the form of streaks, as it has been shown that this can increase motivation for behavior change [13]. If the child chooses a sustainable option at school that day, they will get a point added to their streak. This can give them a sense of pride and accomplishment and promote sustainable eating for multiple days in a row. It also creates an element of competition as children can compare their streaks, which can further increase motivation [13]. The streak can reach a maximum of five days, with each day corresponding to a school day, and resets every Monday. This was decided as to not demotivate students when they lose their streak or when their streak is considerably lower than those of others. Not having an infinite streak also makes this easier to design, as the part of the tray reserved for the streak can be fixed.

As discussed in the related work, research with another tray design has found that it is important for user satisfaction that the overall look and playfulness of the tray matches the age group [8]. Our tray is playful for children as it uses multiple colors for the streak, which is incorporated as LED lights in the rim of the tray. Cute images of nature and animals are also shown on the tray, which we think will appeal to children.

In figure 2 a storyboard is shown which explains how the tray would be used in practice. Usually a limited set of meal options are offered at school canteens, workers could couple the tray to the profile of a child and indicate which meal they chose. The tray would then show the feedback of this meal together with the child's personal streak.

Fig. 2. A scenario of the use of the tray.

Fig. 3. The low-fidelity prototype using paper prototyping.

3.3 Low Fidelity Prototype

Once the concept of the tray was devised, a low-fidelity prototype of the product was created for initial testing of tray design and its functionality. The low-fidelity prototype was made with foam boards and colored paper as shown in figure 3. The size of the tray was determined by using an existing canteen tray at hand. This prototype was evaluated with 20 people. The functionality of the tray was shown through paper prototyping, where different smileys and texts were slid into designated slots in the tray, to demonstrate different sustainability scores. The streak was shown by adding or removing colored pieces of paper on the rim. After the evaluation, no major changes to the design were made, as people were in general positive about the look and functionality of the tray.

3.4 Eating disorders mitigation

One big concern that came out of the evaluation, is that the tray influences children's diet. And that with this vulnerable group, it is crucial to keep eating disorders in mind. Research has shown that neurobiological and genetic predispositions increase susceptibility for eating disorders [5], which can not be prevented through a smart tray. However, our tray focuses on sustainability instead of weight or nutritional values. Shifting the focus from weight or nutrition might decrease the chances of the user developing an eating disorder, as a focus on nutrition increases that chance [5]. In the evaluation, the concern was that the tray would promote eating less or nothing, as this would mean less meat and thus lead to positive feedback. To discourage this behavior, the tray could prompt the child that they should eat more. But, it has been found that interventions designed to reduce dietary restraint are found to be counterproductive and actually lead to an increase in dietary restraint in the long run [6]. So instead the tray will only generate feedback when a main dish is placed on it to never encourage not-eating. So it only gives feedback about food groups possibly containing meat, e.g. sandwiches, as opposed to snacks and drinks like milk or cookies.

Alongside this mitigation, the trays would still be used in the context of school canteens, where the children are supervised by teachers and canteen workers. Like in the usual setting, they will be present to keep an eye out for the children and make sure they are healthy and well.

4 IMPLEMENTATION

In this part we describe the implementation of the Hi-Fi prototype. We used an Arduino (UNO), Arduino hardware, and C++ to implement the prototype. The details on how everything was set up will be elaborated on in the following sections. Firstly, the Arduino and the different hardware elements will be described. Then, the design of the wooden tray will be explained. Lastly, the code will be described and explained by showing multiple listings.

4.1 The Arduino and the hardware

For this project we used an Arduino UNO, different types of hardware and multiple layers of wood to build the tray. We used a breadboard to connect all the hardware elements to the Arduino. We wanted to connect an LCD screen to show text, an LED matrix to show smileys, and an LED strip to represent a streak. We looked at *www.howtomechatronics.com* for the wiring diagrams, so we could see how to connect all the different elements through the breadboard to the Arduino. Once everything was connected, we plugged the USB into a laptop to try the example codes. The result is shown in figure 4.

4.2 The wooden tray

After the hardware was connected properly, we started working on the code and on the wooden tray. For the tray we first had to design the different layers. We decided to use multiplex, since it can be easily cut using a laser, but it is still quite strong material, which is exactly what we needed to build the tray. The first layer is a piece of multiplex of 300x400mm. Then on top there are a few layers with only an edge with the same dimensions, so we could put

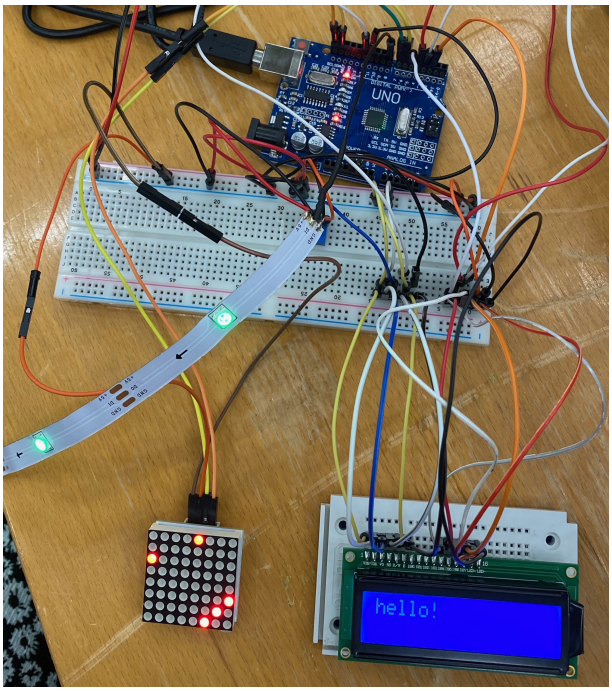

Fig. 4. The Arduino and the hardware.

Fig. 5. The wooden tray.

the hardware in the middle. Then there is a layer which only shows the parts of the hardware we want the users to see, so no wires are visible anymore. This layer also consists of some engravings of animals, to make the tray more attractive for children. Then on top there are two more layers with only edges again, to create a bit of extra height and to put the LED strip in. The result is shown in figure 5.

4.3 The code

The subsequent code was developed to facilitate the tray's logic and to interface with the various hardware components. In general, the following global variables and functions are implemented:

- `realNames`: An array of 10 names to simulate a random user (which in the final product would be obtained from an NFC chip).
- `userName`: The current user's name.
- `streakAmount`: The number of consecutive days the user has eaten sustainably.
- `meatScore`: The sustainability score of the current meal.
- `setup()`: Initializes the hardware components, sets random user data, and displays the initial state.
- `setupMatrix()`: Sets up the LED matrix for smiley face display.
- `drawSmiley()`: Draws a smiley face on the LED matrix based on the `meatScore`.
- `setupLeds()`: Sets up the LED strip for streak display.
- `displayStreaks()`: Displays streaks on the LED strip based on the `streakAmount`.
- `showTextOnLcd()`: Displays a message on the LCD screen.
- `updateLcd()`: Updates the LCD screen with a message based on the `meatScore`.

An overview of the program, and how these functions are implemented specifically will now follow.

```
#include <LiquidCrystal.h>
#include <grove_two_rgb_led_matrix.h>
#include <FastLED.h>
#include <Wire.h>
#include <Adafruit_GFX.h>
#include "Adafruit_LEDBackpack.h"
```

Listing 1. Library Imports

The code shown in Listing 1 imports the necessary libraries for the Smart Tray Prototype. These libraries enable communication with the various hardware components, such as the LCD screen, LED matrix, LED strip, I2C communication, and graphics-related operations.

```
String realNames[10] = { "Alice", "Bob", "Charlie", "Dave", "Eve", "Frank", "
    Grace", "Heidi", "Ivan", "Julia" };
String userName;
static int streakAmount = 0; // the amount of days the user has eaten sustainable
    , yet again, this would normally be obtained from an actual user's NFC
    chip.
static int meatScore = 0; // the sustainability of the meal the user is currently
     eating. This too would normally be set while checking out at the register
    .
```

Listing 2. Variables for User and Scores

The code shown in Listing 2 defines the variables related to users and their scores. The `realNames` array holds a list of user names for demonstration purposes. In a production-ready version, user names and data would be obtained from an NFC chip. The `userName` variable holds the current user's name. The `streakAmount` variable represents the number of days the user has made sustainable food choices, and the `meatScore` variable represents the sustainability score of the current meal.

```
void setup() {
    userName = realNames[(int)random(10)];

    delay(2000);
    setupLeds();
```

```
    setupMatrix();

    drawSmiley();
    updateLcd();
    displayStreaks();
}
```

Listing 3. Setup Function

The `setup()` function shown in Listing 3 initializes the Smart Tray Prototype by performing the following tasks:

- Assign a random user name from the `realNames` array to the `userName` variable.
- Introduce a delay of 2000 milliseconds (2 seconds) before proceeding. This is to make sure all hardware is ready.
- Call the `setupLeds()` function to configure the LED strip.
- Call the `setupMatrix()` function to configure the LED matrix.
- Call the `drawSmiley()` function to display the appropriate smiley face on the LED matrix based on the `meatScore`.
- Call the `updateLcd()` function to display user feedback on the LCD screen.
- Call the `displayStreaks()` function to visualize the user's sustainability streak on the LED strip.

```
const uint8_t smile_bmp[] PROGMEM = {
    B00000000,
    B01000010,
    B01000010,
    B00000000,
    B01111110,
    B01000010,
    B00111100,
    B00000000,
};

const uint8_t mild_happy_bmp[] PROGMEM = {
    B00000000,
    B01000010,
    B01000010,
    B00000000,
    B00000000,
    B01000010,
    B00111100,
    B00000000
};

const uint8_t neutral_bmp[] PROGMEM = {
    B00000000,
    B01000010,
    B01000010,
    B00000000,
    B00000000,
    B01111110,
    B00000000,
    B00000000
};
```

Listing 4. LED Matrix Bitmaps

The code shown in Listing 4 defines the LED matrix bitmap patterns for three different smiley faces: a happy face (`smile_bmp`), a mildly happy face (`mild_happy_bmp`), and a neutral face (`neutral_bmp`). These patterns are displayed on the LED matrix based on the sustainability score of the meal.

```
Adafruit_LEDBackpack matrix = Adafruit_LEDBackpack();

void setupMatrix() {
Serial.begin(9600);
matrix.begin(0x70); // pass in the address
}
```

Listing 5. LED Matrix Setup

The `setupMatrix()` function shown in Listing 5 initializes the LED matrix using the `Adafruit_LEDBackpack` library. It starts the Serial communication with a baud rate of 9600 and sets the I2C address of the LED matrix using `matrix.begin(0x70)`.

```
void drawSmiley() {
    matrix.clear();

    // paint one LED per row.
    // flips the smiley to have correct rotation through j.
    for (uint8_t i = 0; i < 8; i++) {
        uint8_t j = 7 - i;
        if (meatScore == 0) matrix.displaybuffer[i] = neutral_bmp[j];
        else if (meatScore == 1) matrix.displaybuffer[i] = smile_bmp[j];
        else matrix.displaybuffer[i] = mild_happy_bmp[j];
    }

    // Apply shifting/orientation fixes
    uint16_t displaybuffertemp[8];
    memcpy(displaybuffertemp, matrix.displaybuffer, sizeof(displaybuffertemp));

    // Shift data to correct row
    uint16_t tempbuffer2 = displaybuffertemp[3];
    displaybuffertemp[3] = displaybuffertemp[5];
    displaybuffertemp[5] = tempbuffer2;

    // Mirror data
    for (uint8_t i = 0; i < 8; i++) {
        uint8_t tempbuffer = displaybuffertemp[i] & 0xFF;
        displaybuffertemp[i] &= 0xFF00;
        for (uint8_t k = 0; k < 8; k++) {
            if (tempbuffer & (0x01 << k)) {
            displaybuffertemp[i] |= 0x01 << (7 - k);
            }
        }
    }

    memcpy(matrix.displaybuffer, displaybuffertemp, sizeof(displaybuffertemp));

    // write the changes we just made to the display
    matrix.writeDisplay();
}
```

Listing 6. Drawing Smiley on LED Matrix

The `drawSmiley()` function shown in in Listing 6 is responsible for drawing the appropriate smiley face on the LED matrix based on the value of the `meatScore` variable. The function first clears the matrix display and then assigns the correct bitmap to each row of the LED matrix, mirroring the image vertically to adjust for the orientation of the matrix in the tray. The function also fixes issue with the matrix where pixels did not not correspond to their 8x8 grid coordinates, by modifying the display buffer manually.

```
#define LEDS_TO_LIGHT_UP 19
#define FIRST_SEGMENT_START 2
#define LED_DATA_PIN 8
#define LED_BRIGHTNESS 200
#define LED_TYPE WS2811
#define COLOR_ORDER GRB

// lights go from 2 - 16
CRGB leds[LEDS_TO_LIGHT_UP + FIRST_SEGMENT_START];

void setupLeds() {
FastLED.addLeds<LED_TYPE, LED_DATA_PIN, RGB>(leds, LEDS_TO_LIGHT_UP +
      FIRST_SEGMENT_START).setCorrection(TypicalLEDStrip);
FastLED.setBrightness(LED_BRIGHTNESS);
}
```

Listing 7. LED Strip Setup

This section of the code sets up the LED strip using the `FastLED` library. The `setupLeds()` function initializes the strip with the defined LED type, data pin, and color order. It also sets the brightness for the LED strip.

```
void displayStreaks() {


  int segmentSize = ceil(static_cast<double>(LEDS_TO_LIGHT_UP) / 5);
  int currentSegment = 0;
  for (int i; i <= LEDS_TO_LIGHT_UP; i = i + 1) {
    int j = i + FIRST_SEGMENT_START;
    leds[j] = CRGB::Black;
    if (i % segmentSize == 0) {
      currentSegment++;
    }
```

```
    if (currentSegment <= streakAmount) {
      switch (currentSegment) {
        case 1:
          leds[j] = CRGB::Red;
          break;
        case 2:
          leds[j] = CRGB::Blue;
          break;
        case 3:
          leds[j] = CRGB::Yellow;
          break;
        case 4:
          leds[j] = CRGB::Purple;
          break;
        case 5:
          leds[j] = CRGB::Green;
          break;
      }
    }
  }

  FastLED.show();
}
```

Listing 8. Displaying Streaks on LED Strip

The `displayStreaks()` function shown in Listing 8 is used to display the sustainability streaks on the LED strip. It calculates the segment size based on the number of LEDs to light up and iterates through the LEDs, setting each LED's color based on the current segment and the `streakAmount` variable. Finally, it updates the LED strip using the `FastLED.show()` function.

```
const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

unsigned long lcdTimer = 0;
void showTextOnLcd(String textToDisplay) {
  lcd.begin(16, 2);
  lcd.clear();

  int textLength = textToDisplay.length();
  int lcdLength = 16;

  int scrollIndex = 0;
  while (scrollIndex <= textLength - lcdLength) {
    unsigned long currentMillis = millis();
    if (currentMillis - lcdTimer >= 600) {
      lcdTimer = currentMillis;
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Hi, " + userName);
      lcd.setCursor(0, 1);
      lcd.print(textToDisplay.substring(scrollIndex, scrollIndex + lcdLength));
      scrollIndex++;
    }
  }
}
```

Listing 9. Setup LCD screen

This section of the code in in Listing 9 sets up the LCD screen and defines the `showTextOnLcd()` function for scrolling text. The LCD screen is initialized with the specified pin connections, and the function displays the scrolling text by updating the display at a set interval based on the `lcdTimer` variable.

```
void updateLcd() {
if (meatScore == 0) showTextOnLcd("You've been eating a lot of meat, try to eat
      less!");
else if (meatScore == 1) showTextOnLcd("You've been eating very sustainable, nice
      job!");
else showTextOnLcd("You've been eating okay, but there's room for improvement!");
}
```

Listing 10. Updating LCD Screen with User Feedback

The `updateLcd()` function is responsible for updating the LCD screen with user-specific feedback based on their `meatScore`. The function uses the `showTextOnLcd()` function to display a scrolling text message with feedback tailored to the user's sustainability score:

If the `meatScore` is 0, it shows a message encouraging the user to eat less meat.

If the `meatScore` is 1, it praises the user for their sustainable eating habits.

Otherwise, it suggests that the user is doing okay but could improve their sustainability effort

5 EVALUATION

5.1 Study Design

For the study design, we decided to test the prototype with parents instead of children, as it is more ethical since minors can not give consent. Additionally, it was decided not to conduct the study in actual school cafeterias, as there is a limited number of those in the Netherlands with none in close proximity. Instead, semi-structured interviews conducted among parents with children aged 4 to 14 and their opinions were gathered on the effectiveness and functionality of the tray. However, this meant not actually being able to measure the effectiveness of the tray by having children use it.

It was ensured that all participants were informed about the aim of the study and consented to the interview. Furthermore, the study design was approved by the ethics committee of Utrecht University. We decided to interview the parents to gain deeper insight into their opinions. This qualitative approach was especially beneficial as we sought to gain insight into the subjective experiences, preferences, and convictions of both parents and children. Directly surveying parents also had the additional benefit of identifying any ethical concerns parents may have regarding the use of the tray in school cafeterias. The results of the study were evaluated by comparing the answers of the parents.

5.2 Apparatus

The study was conducted at Utrecht University as well as the Bibliotheek Neude. The participants of the study were interviewed individually in an academic building. The smart tray was shown which was connected to a computer to run the prototype. Additionally, a smartphone was used as an audio recorder.

5.3 Procedure

First, the interview participants were asked if they would have time for a quick interview of about 15 minutes for a master course. If so, they were asked if they have children within the age range of from 4 to 14. Then the purpose of our interview was explained; for the master course 'Interaction Technology Innovation' a smart tray was developed to be used in primary school canteens. The purpose of the tray is to make children more aware of a sustainable diet, for now the focus herein is on meat consumption. A prototype of the product was created and parents' opinions are being collected on whether they believe the tray would be suitable for this purpose. Moreover, it was asked if it would be possible to show the prototype and ask a couple of questions about it as well as record the interview. The participants were also informed that the answers would be anonymous. Once the participants agreed, their gender and age were noted, as well as the age of their children. Finally, the interview was started by showing the smart tray and explaining the functions of each of the components. Next, it was shown what happened if the child chooses a meat-heavy lunch at their canteen and what happened if they

choose a meat-free lunch, etc. The evaluation was carried out by asking the following questions:

(1) What do you think children would think about the design of the tray overall?
(2) Do you think that the use of such a tray in canteens to raise awareness is appropriate for children?
(3) Do you think the feedback from the tray is sufficient?
  (a) Do you think the streak element would motivate children to eat more sustainably?
  (b) What about the smiley and text feedback?
(4) Do you think that if your child were to use the tray over a few weeks, it would improve their awareness of sustainable food?
(5) Do you think it will motivate your child to change their behavior and choose different food options?

Furthermore, the evaluation was focused on gathering people's feedback about possible ethical concerns. Thus, possible unethical scenarios have been sketched out and presented to the participants. These dystopian scenarios, shown in figure 6, included the development of unhealthy diets or eating disorders. The use of the smart plate could lead to children obsessively choosing certain foods and only reaching for products that are labeled as environmentally friendly. Moreover, misleading claims may be made by labeling food as eco-friendly although this is not the case.

(1) Do you have any concerns regarding the use of the tray?
  (a) Do you consider the scenarios we sketched out concerning?
  (b) Do you believe they are probable and pose a risk?
(2) Do you believe they are probable and pose a risk?
(3) Is there anything you would improve on the tray?
(4) Do you have any other comments?

Lastly, the participants were thanked for their time and insight as it was greatly appreciated.

5.4 Participants

The evaluation was conducted at the Utrecht University Science Park buildings as well as the Neude public library in Utrecht. The interviewed participants were a convenience sample of 20 parents with the criteria of having a child aged between 4 and 14. Altogether, the interviewed parents were between 35 and 48 years old, with 8 males and 12 females. The evaluation was conducted by presenting the tray and asking the questions mentioned above while the interview was being recorded to be evaluated later. Participants were given the tray and the different modes of the tray were shown.

6 RESULTS

Overall, the tray was received positively and parents believed that its use was appropriate for children. The results have shown that the design of the tray might be more suited for younger children up to the age of 10 as they believed the engraved animal pictures will be perceived as too childish. Every interviewed parent showed positive reactions to the use of the streak, emojis, and text display as motivational tools. Especially the colorful streak has been mentioned as both the design and the function appear very engaging. Although parents felt that the tray would increase their children's

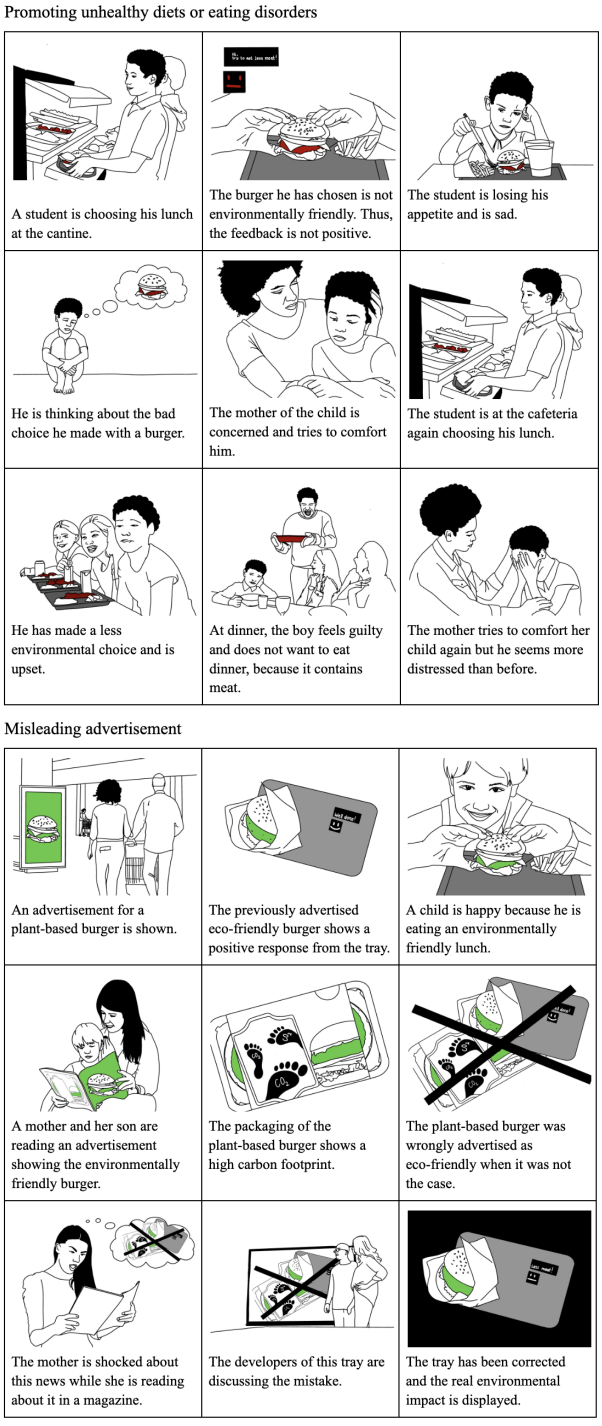

Fig. 6. The dystopian scenarios.

Interview participants					
	P1	P2	P3	P4	P5
Age	42	48	39	40	36
Gender	f	m	f	f	m
Age Children	5, 5, 13	10, 12, 14	6	6, 9	8, 11
	P6	P7	P8	P9	P10
Age	46	45	42	35	40
Gender	f	f	f	m	f
Age Children	5	14	12, 17	11	4
	P11	P12	P13	P14	P15
Age	41	47	45	43	38
Gender	m	m	f	f	m
Age Children	6, 8, 16	2, 5	2, 9	4	13, 15
	P16	P17	P18	P19	P20
Age	39	41	40	35	37
Gender	f	f	m	m	f
Age Children	12, 13	3, 5	12, 15	4, 7, 8	8

Table 1. Table showing the age, gender and children's age of the interview participants.

awareness of their food choices, 5 parents were concerned that their children would not implement this knowledge in their daily lives due to their children being picky eaters and enjoying fast food. Parents mentioned it might be difficult to change these eating habits. Furthermore, 55 percent of parents felt that the development of obsessive behavior was a possibility. For this reason, parents expressed concerns that teachers are particularly important. For example, one parent said; "I am concerned that my child would feel guilty if she chose an unsustainable option and would also feel ashamed. The shame that my child might feel could turn into obsessive behavior or even trigger an eating disorder." 70 percent of all parents thought the dystopian scenario of developing an eating disorder was possible. In contrast, only 25 percent of all parents considered it possible that the test could be manipulated with false data. However, no other concerns were expressed. Finally, the improvements were discussed in detail. Parents felt that a more age-inclusive design without the animal pictures would be beneficial, as well as more detailed feedback to better inform children about their environmental impact.

7 DISCUSSION

7.1 Potential ethics issues

Though the EcOO plate has users' best interests in mind, it produces potential ethical issues. With the targeted user base being so young, the plate forms an environment that is susceptible to targeted advertising. Not only can companies market their products as being sustainable, but thus make more revenue when children are incentivized to pick those. But the tray also has the potential to suggest more sustainable options in the future. Through (paid) advertising, the tray could become profit-oriented, and advertise brands that do not have sustainability in mind. Likewise, the tray could advertise hunger suppression, as consuming less can be "more" sustainable, and as mentioned before the tray would inadvertently be encouraging eating disorders. These negative side effects could be mitigated by always having a human present to check whether there is enough food on the tray, hopefully preventing eating disorders. Additionally, the plate could be configured in such a way that it does not provide feedback unless a certain nutritional threshold is passed. Lastly, to prevent the plate from becoming a space for advertisements, it could be tied to a non-profit initiative, avoiding the need to generate income.

7.2 Social impact

Our smart tray could help raise awareness among children in many countries about the environmental impact of their meat consumption. Educating them on this matter and engaging them in a gamified way to eat less meat, encourages them to reflect on the sustainability of their food choices. We hope that learning this information from a young age it will stick with them for the rest of their lives. This could be a huge step to reduce the environmental impact of food production, as hopefully many of these children grow up with sustainable habits around food. This increased awareness could also incite them to consider sustainability in other areas of life, like transport and fashion. We hope that the habits and values learned with our product will be a great contribution to the fight against climate change.

7.3 Tangibility, materiality, and embodiment

Our smart tray has benefits by being a tangible intervention. In opposition to digital feedback, our tray gives direct feedback that is intuitive as it is immediately visible after choosing the meal. It also has a playful design and uses gamification which is engaging and interactive for children. The tray can also be seamlessly incorporated into the context of school canteens, as it is naturally used to carry the food.

The high-fidelity prototype of the tray is made out of wood. This is a durable material and easy to work with. However children might spill their food and drinks, so for the actual product another material should be used that is waterproof and doesn't stain, like plastic. It should also be thin and light-weight, so it is easy for children to carry.

7.4 Limitations

Throughout the entire project, there was difficulty with gathering user feedback. Because the Lo-Fi prototype took relatively long to conceptualize, it became difficult to iteratively go through the design process, also making breadth-first research problematic. Moreover, because of our very specific target audience (guardians of young children) and context (eating at school canteens), it was difficult to find participants who fit our requirements. By prioritizing iterative prototyping and user feedback, additional insights and results could have been gathered.

7.5 Future work

While this research was an important first step in the development and evaluation of the smart tray, there is much work to be done before it can be successfully implemented in canteens. First of all there is a need for further user testing, especially with our target audience

of children and their guardians, and in the context of canteens. The feedback will help us improve the design and functionality of our product and make sure that it matches the user needs of this specific group.

For the functionality of the tray, the ease of use could be greatly enhanced if it could automatically recognize what food is on the tray. At the moment the canteen workers have to manually add the food options for the day to the system, so that the information can be sent to the tray via NFC. This added feature could for example be implemented with computer vision technology.

In addition, the feedback messages displayed in the textbox could be improved. As of now, these messages are very simple, telling the user that they are doing a good job or could be doing better, or that their meal choice is sustainable or not. The scope of this project was not to educate children on what it means for something to be sustainable. In the future, this could be done by describing exactly what factors of the meal lead it to be (un)sustainable. For example, when a child chooses a beef burger, it could explain that beef production requires way more land and water than for example chicken production. Important to keep in mind with this feature is that the information stays easy to understand for children.

As mentioned before, we would like the capabilities of our product to be extended to include other aspects of a sustainable diet beyond meat consumption. Even though meat consumption is the biggest contributor to environmental pollution from our diet. Other important factors to consider are the production and transportation of food, waste generation, and nutrition considerations. Since we cannot expect the canteen workers to figure out all this information and provide it to our system. There should be a way developed for the system to be linked to the food suppliers, so it can infer these factors for as far as this is possible.

8 CONCLUSION

The personal and global impact on the environment can be significantly reduced through diet, in particular through meat consumption. For this study a smart tray was developed which had the aim of raising children's awareness of the environmental impact of their meat consumption. And through this awareness, to motivate them to eat less meat. The tray gives feedback on children's meal choices through textual feedback, along with visual feedback through a display with a smiley, and a streak score. The tray design allows the product to be easily integrated in school canteens, thus reaching a large audience.

The tray was evaluated with 20 parents, who were shown the prototype and asked about their perceived effectiveness of the tray. Overall the tray was received positively and was believed to be effective and appropriate for children. However, some parents believed the tray would not impact their child's diet as they are picky eaters or love fast food. Parents moreover mentioned their concern for the tray causing obsessive behaviors in children, which could potentially trigger an eating disorder. This risk can potentially be mitigated by only giving feedback when a reasonable portion of food is on the tray and by only focusing the feedback on meat consumption.

The research question this study has attempted to answer was *'Can we make children aware of the environmental impact caused by their meat consumption using feedback and gamification?'* According to the evaluation, parents do think the feedback and gamification elements of the tray are suitable to raise awareness about this topic in children.

Though, future research is necessary to accurately answer this question, as the tray still needs to be evaluated with children in the context of school canteens. There are additional opportunities for improvement, such as more detailed feedback, as the messages do not explain yet why meat is unsustainable. The focus of the product could also be extended to include other aspects of a sustainable diet beyond meat consumption. And the usability of the tray could be improved through by automatically inferring the food on the tray with computer vision.

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