Car Safety Sensor

Keeping Children Safe and Cool in Cars

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E4: Section 3 Team 3
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November 2017

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Abstract

For this project, we worked with Ms. Cowles, Executive Director of Kids In Danger, a nonprofit organization that aims to improve child product safety, in order to address the problem of children being left in hot cars without a parent present. This report documents our process of developing a safety device that can be installed in a car to prevent this issue. Our final prototype uses two buttons within seat cushions to sense the child and parent's presence, and then lights up an LED when the parent leaves the child alone for a given amount of time. Although this prototype satisfies all of our client's objectives and constraints, it mainly serves as proof of concept for a more technical design. We outline the recommendations for such a design, such as implementing wireless technology to minimize potential hazards and mobile app integration for a more streamlined alert system.

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Introduction

Problem Statement

Kids In Danger (KID) is a non-profit organization dedicated to improving child product safety. They work to identify products that are potentially harmful or deadly to children, then work with external companies and organizations to improve the quality and design of these products to create a safer environment for children. Nancy Cowles, executive director at KID, worked with us throughout the project to develop a product to help prevent children from overheating as a result of being left in a car without a parent.

Injuries or death of children being left or forgotten in cars is an issue that many companies and organizations have tried to eliminate. A situation where a parent leaves their child in the car on warm days can lead to a child overheating and experiencing heat stroke. There are currently several products that exist to help eliminate this from occurring. However since this issue is still prevalent, KID hopes to find a way to completely eliminate this problem.

We were asked to design a product or device that addresses any issue that can lead to this situation occurring. This may include keeping a parent from leaving a child in a car, alerting the parent or authorities or keeping the temperature in the car cool enough until help arrives.

The initial problem statement given to us by Ms. Cowles states:

Research the phenomenon of an overtired parent forgetting their child in the back seat and design a solution.

We revised this problem statement to limit our design space and eliminate biases and implied solutions. Our revised problem statement is:

Create a device designed to prevent parents from forgetting their children in car seats.

Background and Research

In 2017, there were 40 reported cases of child vehicular heat stroke in the United States. Of these deaths, 54% occurred when a child was forgotten in the car, 28% occurred when a child was playing in an unattended car and 17% occurred when a child was intentionally left in a car[1]. Since the circumstances regarding leaving a child in a car differ, companies have released several products to address different aspects of the problem.

Oasis is a product currently on the market which works to prevent a child from having heat stroke by monitoring the temperature of the car and blowing cool air once the temperature in the car has risen to dangerous levels. The authorities and parents are then contacted and alerted of the situation[5]. This solution can prevent heat stroke, but does not address the underlying issue that the child is left alone in the car. This product is currently still in development and not yet available to buy.

Sensorsafe is a technology found in some car seats from the brand Evenflo. There is a receiver that goes into your car's diagnostics port, a socket located inside a vehicle that accesses various vehicle subsystems where small receivers can be installed to tap into a car's computer system. That receiver communicates with the car seat's smart chest clip – letting the driver know through a series of chimes whether a child is still in the seat after the car is turned off[6]. This product addresses the underlying issue but the complexity and hefty $150 price of the product may make it less marketable to parents. Our liaison, Ms. Cowles, hopes to see a product that is more affordable and therefore accessible to more parents.

Interviews

In order to find out what kinds of products parents would be willing to buy and setup, our team conducted a series of interviews. We interviewed several professors from the Claremont Colleges as well as several other parents, which provided us with valuable information about the desires of potential clients. Some significant findings include that most interviewees expressed concern with desensitization and suggested that the device not require any activation. One parent told us that her car automatically reminds her to check her car seat every time she parks, but since it occurs so frequently, she now ignores it. This points to the need for the device to only notify the parent when absolutely necessary. The desired means of notification, however, varied significantly between individuals, so we have to rely solely on the design process to choose the optimal means for notifying the parent.

Methodology

Project Definition

To limit our design space, we began by forming and revising a problem statement, identifying objectives and constraints, and defining functions. From our initial project description, we identified an initial problem statement: "Research the phenomenon of an overtired parent forgetting their child in the back seat and design a solution."

This problem statement reflects the design space that Ms. Cowles initially gave us - we had no constraints on what aspect of the issue we could address. However, we knew that in order to design an effective solution we would need to focus on a specific issue. From our research, we realized that the situations with the highest mortality rate are where the parent entirely forgets their child[2]. As such, we decided to focus our design on preventing a parent from forgetting their child in the car. We also realized that children who were of the age range to be in a car seat were represented nearly 50% of the deaths in these scenarios[3]. With both of these factors in mind, we cut down our design space to reach our final problem statement: "Design a system that prevents a child from being left in their car seat without a parent present."

Constraints

To understand the limitations of our newly defined design space, we set out to define our project's constraints. Constraints are necessary requirements of our final design, which the design either complies with fully or not at all. Following our initial meetings with our client, we generated the following constraints:

- *The device must cost $125 to prototype.*
    - Our E4 project budget states that our design must cost under $125 to prototype.
- *The device must cost under $30 for a consumer.*
    - From our interviews, $30 was a reasonable cost for the parents for a safety device.
- *The device must work autonomously.*
    - We set out to address scenarios where the parent does not have the presence of mind to realize that their child is still in the car. As such, we realized that our design must work independently of the parent and child, and thus work autonomously.

Objectives

With this design space in mind, our team set out to define objectives for our design, or the desired attributes for our design. To methodically categorize all of our objectives, we organized our them into an objective tree, shown below:

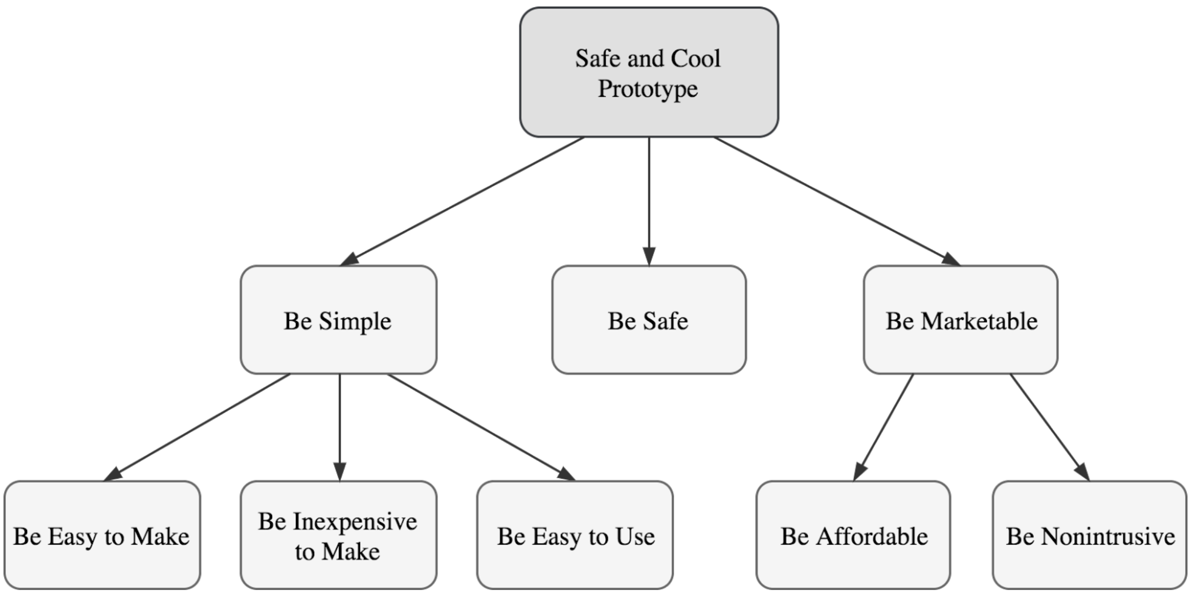


Figure 1*: Objectives tree depicting the hierarchical organization of general to specific objectives we must include in our final design*

Next, in order to rank our objectives, we created metrics for each of our objectives, and defined reasonable boundaries for our numeric metrics.

- *Be Safe*: Comply with safety standards
- *Be Simple:* Straightforward design
  - *Be Easy to Make:* Time to manufacture [hours] {< 5}
  - *Be Inexpensive to Make:* Cost to a manufacturer [dollars] {< 30}
  - *Be Easy to Use:* Time to set up [minutes] {< 15}
- *Be Marketable:* Attractive to users
  - *Be Affordable:* Cost to the customer [dollars] {< 30}
  - *Be Nonintrusive:* Inconvenience to customer [survey 1 to 10] {<5}

We then ranked our objectives using a pairwise comparison chart to determine their relative importance. All of the objectives are organized into corresponding rows and columns. If the row objective is viewed as more important than the column objective, we enter a 1. If the row objective is viewed as less important than the column objective, we enter a 0. We then summed up each row objective's total, where a larger number corresponds to greater importance. We then sorted our objectives in order of importance to determine how to structure our design process.

Primary Objectives	**Safe**	**Marketable**	**Simple**	**TOTAL**
Safe		1	1	**2**
Marketable	0		0	**0**
Simple	0	1		1

Table 1a: *Pairwise Comparison Chart used to rank our primary objectives*

Secondary Objectives	Affordable	Nonintrusive	Easy to Make	Cheap to Make	Easy to Use	**TOTAL**
Affordable		0	0	1	0	**1**
Nonintrusive	1		0	1	1	**3**
Easy to Make	1	1		1	1	**4**
Cheap to Make	0	0	0		0	**0**
Easy to Use	1	0	0	1		**2**

Table 1b: *Pairwise Comparison Chart used to rank our secondary objectives*

Overall, we found that the safety of the device is of paramount importance, followed by the simplicity and finally the marketability. Within the objectives to be marketable and simple, we found that being easy to make is very important, and that the objectives concerning cost are less important because they are already limited by our constraints.

Conceptual Design

After limiting our design space, we developed more focused functions that describe what we want our prototype to do. We came up with the four functions to sense the child's presence, sense the parent's presence, receive input from sensors, and transmit a signal. Then, we created a morph chart in order to list all the possible means for each function.

Functions:	*Means:*						
Sense child's presence	Car Seat Weight Sensor	Back Door Sensor	Live Recording	Facial Scanner	Motion Sensor	Heat Sensor	Car Seat Buckle
Sense parent's presence	Driver Seat Weight Sensor	Front Door Sensor	Live Recording	Facial Scanner	Motion Sensor	Speedometer	GPS tracking
Receive input from sensors	Simple Circuit	Arduino	Raspberry Pi	Car Electrical System	BeagleBoard		
Transmit a signal	LEDs	App	Bracelet	Car Alarm	Live Stream	Calls Parent	Keychain

Key: Yellow = Weight Sensor, Red = High Tech App, Blue = Motion Bracelet

Table 2: *Morphological Chart listing possible means for each function, from more practical to less practical reading left to right; 3 design alternatives highlighted in different colors*

Design Alternatives

With our objectives, constraints, and functions in mind, we developed three different design alternatives which each implemented different means for each function.

Our first design alternative is a simple device that consists of a weight sensor on the driver's seat and in the car seat, a simple circuit, and a strip of LEDs around the car. We call this simple design the Sensor Circuit to describe its main components.

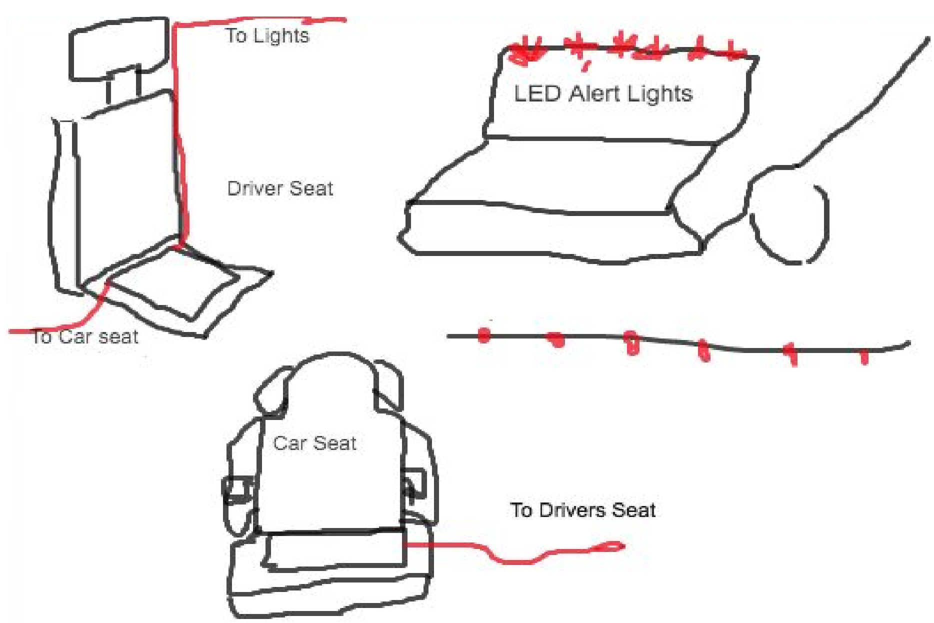


Figure 2: *Sketch of Sensor Circuit, our first design alternative*

We then chose to include the means with more advanced technology implementations in our second design alternative, which we call the High Tech App. The High Tech App utilizes a facial scanner which would provide input to our Arduino, and then send the alert to the parent's phone via the app. A GPS location tracker would keep track of the parent's location, and alert the parent when the distance away from the car is outside of a certain range and the child is still in the car.

***Figure 3**: Sketch of High Tech App, our second design alternative*

Our final design alternative incorporated the remaining pragmatic features from our morph chart, which we christened the Motion Bracelet. As indicated by the name, this alternative uses motion sensors to send input to a Raspberry Pi, which would then send an output of sound, vibration, and light from a sleek, low-profile bracelet that the parent would wear.

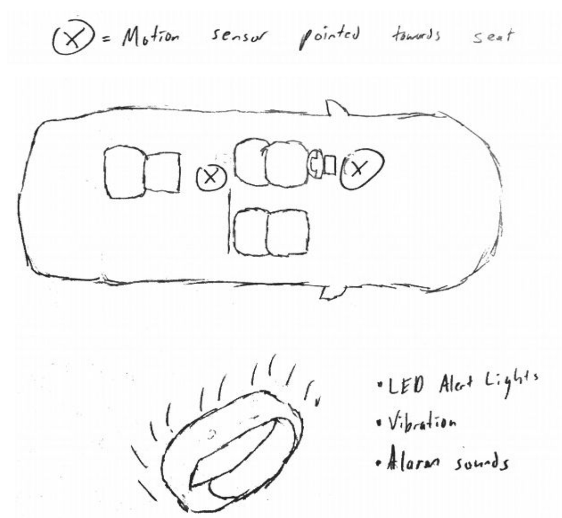


***Figure 4**: Sketch of Motion Bracelet, our third design alternative*

Choosing a Design

To choose the design that would best perform our objectives, we created a best of class chart to rank each of our designs.

Objectives	*Sensor Circuit*	*High Tech App*	*Motion Bracelet*
Be Safe	2	1	3
Be Easy to Make	1	2	3
Be Easy to Use	2	1	3
Be Nonintrusive	3	1	2
Be Affordable	1	2	3
Be Cheap to Make	1	3	2

Table 3: *Best of Class Chart ranking our three design alternatives in their conceived performance of each objective*

The High Tech App ranked higher than the other designs in our top objectives, but once we began thinking about the logistics of making it, we quickly realized that we had neither the time nor resources to create such a design. Instead, since the Sensor Circuit also ranked highly, we decided to incorporate some of its features into a proof of concept design for the High Tech App. We describe below our final means to perform each of the functions.

- *Sense Child's/Parent's Presence*: To accomplish this function we determined that it would be most cost effective to use the same method to sense both the child's and parent's presence. In terms of simplicity, cost-effectiveness and consistency, we chose to use weight sensors that can be placed within the driver's seat and car seat.
- *Receive Input From Sensor*: To accomplish this function, we chose to use a simple circuit connected to an Arduino. This is the most feasible mean for meeting our budget.
- *Transmit a Signal*: This function was one of the more difficult to decide upon. We at first decided that an app would be most effective for alerting parents of the situation. However, based on time and budget constraints, and also the fact that LEDs could also be an effective way of alerting the parent, we decided to use LEDs as our mean for our design.

Prototype Evaluation

Design Iterations

Once we began constructing our final design, we encountered obstacles with our sensors and transmission devices. After purchasing load cells, we found that their functionality extended beyond our needs in that they measure the exact weight input rather than a simple on or off input. Therefore, the load cells we planned to use as weight sensors involved advanced code and confusing circuit design, and the speakers were similarly troubling. Both devices required op-amps with poor documentation and equally poor explanation of the corresponding C++ code. Rather than struggle and potentially short something, we instead decided to reevaluate our chosen means.

After some reflection, we decided on new design features, which better fulfill our objective to be simple. For our sensors we decided to use buttons, which suited our goals since we focused primarily on having a binary output from our sensors (the parent and child are each there or not). For our output, we settled on outputting this simplified input to light an LED, since our design is largely a proof of concept for a more complicated design. Below we depict the load sensor and speaker we initially tried to use on the left, and the button and LEDs that we ultimately included in our final design.

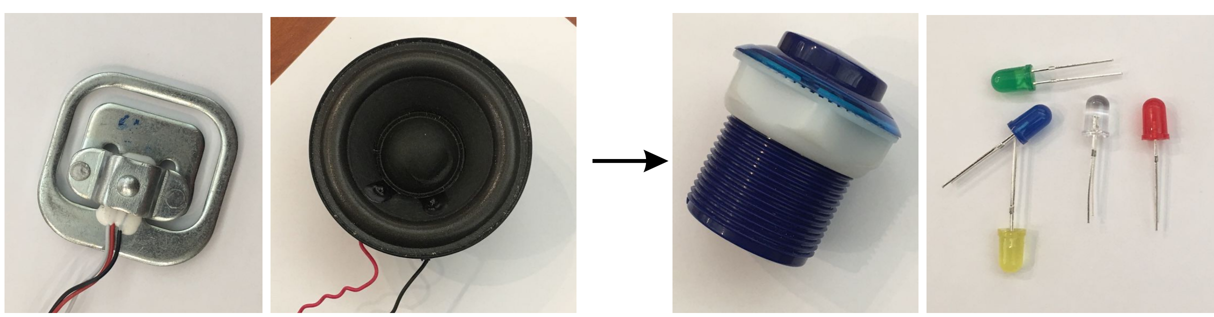
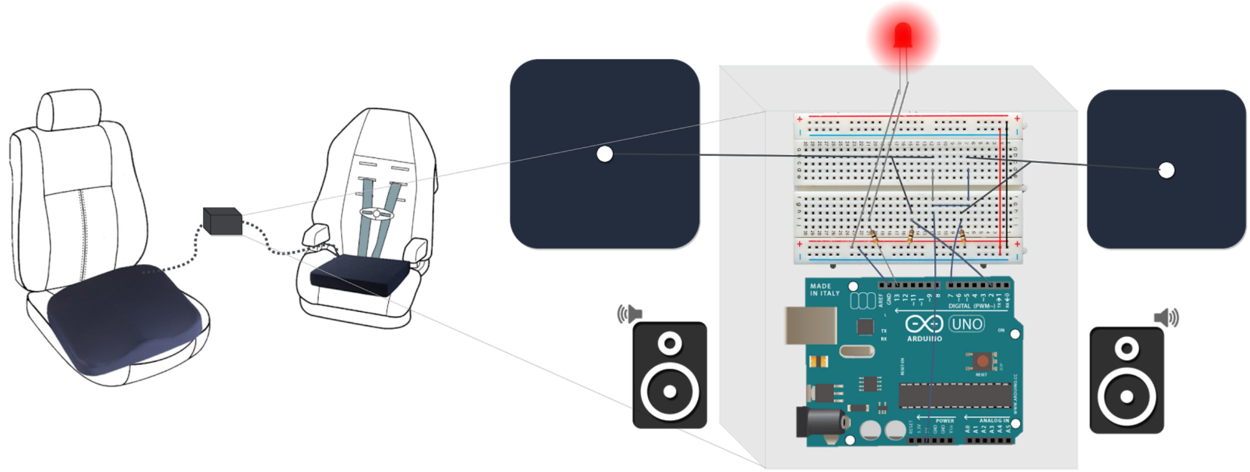


Figure 5: *Our initial sensor and output, compared to our final sensor and output.*

We first wrote C++ code for the Arduino to light a single LED when a button was pressed. We then wrote code to light the LED only when the child button was pressed without the parent button being pressed. Once we had tested this system, we then began to work on our final prototype.



KEY: ◯ = buttons, = LED, = speakers (later removed)

Figure 6: *A visual representation and corresponding schematic of our prototype following several revisions.*

Feedback

After each iteration of our design, we received feedback for potential improvements and revisions. One concern that our classmate brought up was the unequal distribution of weight on the cushion and whether or not the button would always be able to sense presence. Potential modifications include using a much wider button or a thin film pressure sensor. Another problem that our liaison, Nancy Cowles, called attention to was the safety of the car seat after adding a cushion which could modify the position of the child. Two possible solutions are incorporating the button into the car seat itself, or significantly reducing the thickness of the child cushion. Since integrating the sensor into the padding of the car seat required additional installation labor and customization, we chose to implement the latter option by removing some padding from the cushion.

Functionality Test and Results

After receiving peer and liaison feedback, we decided to test our prototype's ability to successfully detect an unattended child. For this test, we devised the following procedure to mimic a typical loading process for a parent and child. First, we placed an object resembling a child on the child cushion (as children are loaded into the car first), and then instructed an individual to sit on the parent cushion (so our device now replicates a car in transit). We then had our "parent" release their cushion, while our "child" kept their cushion compressed (so as to mimic the child being left in the car). We measured a successful trial when the LED lit up only at this final stage, and measured a failure if the LED failed to light up or lit up at any of the other stages. Ideally, we would independently test the four functions of our device: sensing the child's presence, sensing the parent's presence, receiving the input from sensors, and transmitting a signal. However, since all of our functions needed to operate in conjunction to produce our output, we decided to simply test the overall functionality with this singe test. We set our minimum success rate at 9.5/10, which seemed reasonable from other designs we researched. Though we recognize that a final manufactured prototype would be subject to more stringent safety regulations, we feel that this is a reasonable expectation for prototype testing.

We first performed some preliminary tests to check that our prototype still worked, and found that the child cushion was unable to detect the presence of lighter object, so we removed some padding, then performed our actual tests. We performed 10 trials for 5 different sets of parents and children to account for varying weight distributions. The following table visually represents our data:

Set	Trials									
1										
2										
3										
4										
5										

Key: Green = SUCCESS, Red = FAILURE

***Table 4**: True Positive test results showing the success and failures of each test to illustrate the error rate*

We found that our prototype had a 96% average success rate, which was within our boundary for success. As such, we found no need for design improvements to improve the functionality of our device. With the functionality testing done, we moved on to test our prototype's success regarding our objectives.

Objectives Test and Results

To measure our final prototype's success at accomplishing our objectives, we revisited our objectives and corresponding metrics. For our easily measured objectives, we created a table to compare our prototype's actual values for these objectives with our theoretical metrics. As you may note below, we were not able to measure the inconvenience of our prototype due to time and budget constraints. Since our proof of concept model would have to be created before its inconvenience could be measured, we were not able to measure its inconvenience to the customer as well.

Objective	Metric	Reasonable Metric Range	Prototype Value	Proof of Concept Value
Be Easy to Make	Time to Manufacture	< 5 hours	4 hours	2 hours
Be Inexpensive to Make	Cost to Manufacture	< 30 dollars	$57.06 *	$27.32 *
Be Easy to Use	Time to set up	< 15 minutes	15 minutes	5 minutes
Be Affordable	Cost to Customer	< 30 dollars	$57.06 *	$27.32 *
Be Nonintrusive	User Inconvenience	< 5 / 10 (survey)	N/A	N/A

*See Appendix C

***Table 5**: A comparison of our metric range to prototype's objective attributes and our theoretical values for our proof of concept*

As shown in the table, our device was successful at two of the four metrics that we were able to measure. This failure was largely due to the cost of the Arduino ($28), which by itself almost put us over budget. However, as we mention later in Recommendations, our proof of concept prototype would incorporate a mass produced custom microcontroller in its place. This change, combined with other manufacturing optimizations, would reduce the cost of a manufactured product to within a reasonable range for all of our metrics (See Appendix C).

Final Design

Since our prototype performed relatively well during testing, we made few changes for our final design. Our device performed well when we varied the distribution of weight across the cushions by testing with various individuals and objects. Therefore, we concluded that keeping the button in the center of each cushion would be appropriate. Then, since our liaison suggested that the cushion might cause a safety hazard when placed in the car seat, and a thicker cushion was unable to detect the child, we removed padding from the child cushion and even suggest incorporating the button into the car seat to further prevent secondary safety hazards. Our final prototype is pictured below:

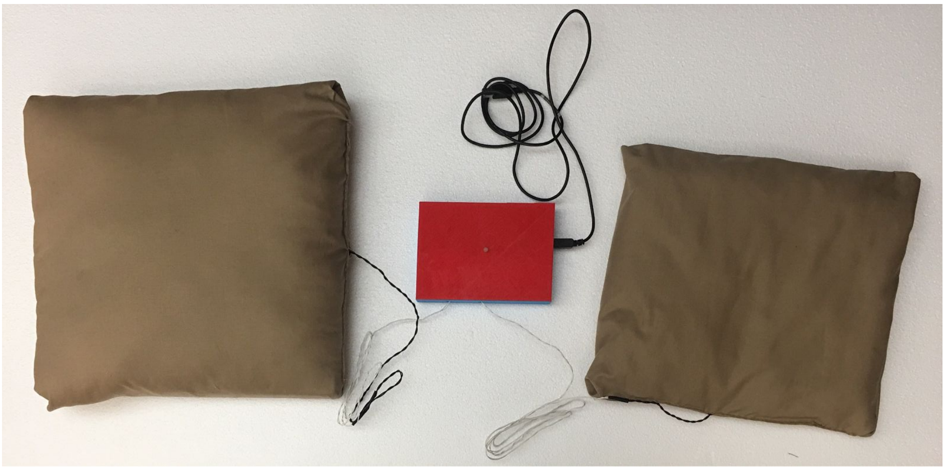


Figure 7: *A picture of our final prototype (note the slightly visible LED in the middle of the red lid).*

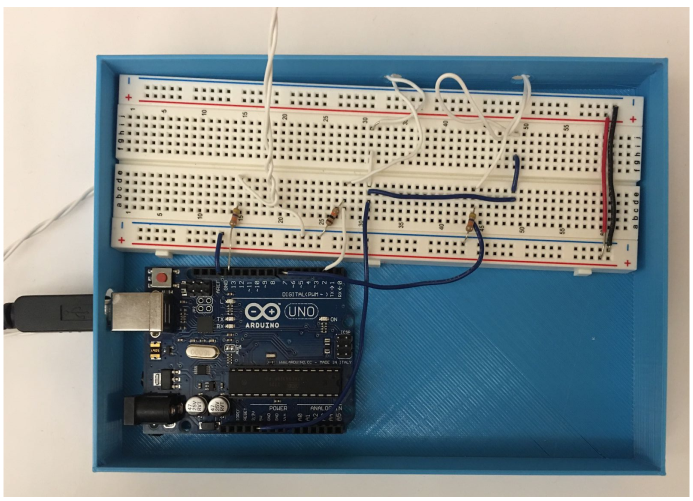


Figure 8: *A close-up inside our red/blue box, with the white wire on top leading to the LED.*

Our final design would also include an app interface used to notify the parent. Some features that we wanted to include in our app include an alert screen, snooze / dismiss buttons for a false alert, the ability to control the snooze time and notification delay, and various other options. A potential concern brought up by our liaison was that the problem of leaving a child in a car often arises when someone other than the parent drives the child. However, we feel that if the parent is still notified, the parent can easily relay the alert to the driver of the child. A potential design for the app interface is shown below:

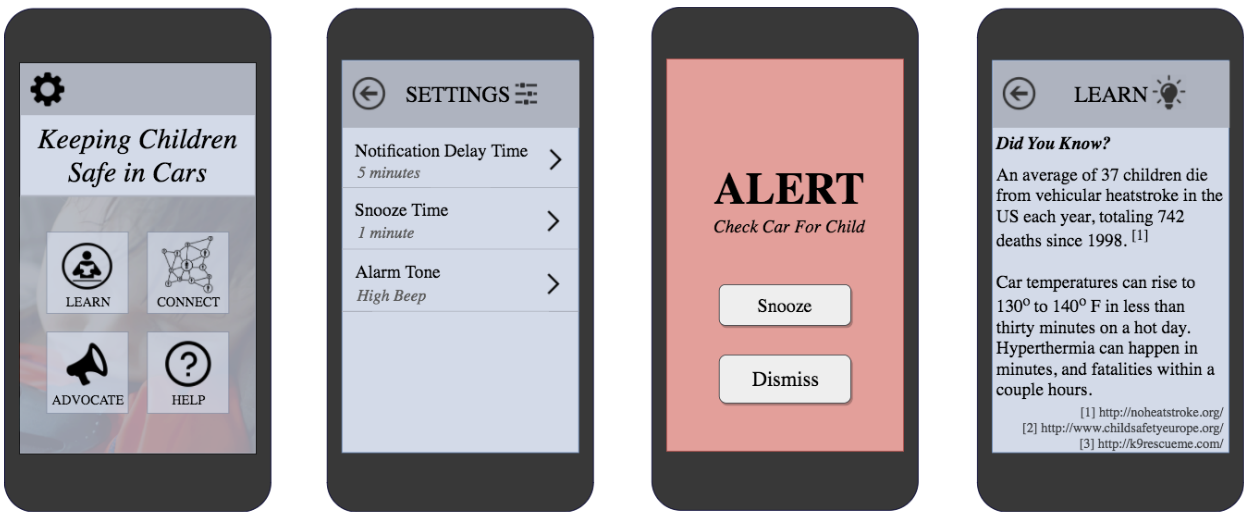


Figure 9: *One potential design for the app interface.*

We decided to include a home screen with options to learn more about the issue, to connect with other parents experiencing similar struggles, to advocate for the problem of car safety to government officials, and to receive help with the application. The app is designed to raise awareness of the problem of child safety in cars and to provide functionality with the button and Arduino system.

Recommendations

Although our final prototype satisfied all of our client's objectives and constraints, this design is still a proof of concept for a more complex, streamlined iteration of the High Tech App. Such a design would ideally have several additional features, such as a functioning app and means of communicating between the buttons, Arduino, and app.

Since this design is a safety feature involving children inside a motorized vehicle, any final prototype would be subject to the appropriate safety regulations, and as such would likely undergo several more revisions beyond what we have envisioned. Wireless receivers that communicate between the hub and the two buttons could improve the safety of the device by limiting the potential hazard of dangling cords. Additionally, incorporating the car seat button (which currently sits in the cushion) into the car seat itself could prevent possible safety hazards involving any undesired displacement of the child in the car seat.

It would also feature a variable delay on the alarm proportional to the length of the car trip, which was inspired by our feedback from our interviews. Most importantly, this design would take our output from the Arduino and communicate with an app installed on the parent's phone to send a wireless alert to them. We also advise including multiple options for notifying the parent, such as the choice between an app and a speaker on the car's exterior.

Another issue that the final product would have to address would be the power source for the Arduino. Currently, we've powered the Arduino via USB connection to our computers, but even connecting a power brick would face the issue of eventually running out of power. A more advanced system could incorporate a power brick that could draw power from the car's battery via the standard DC connector. However, since this system is presumably going to be utilized in hot climates, future designers could potentially implement a system utilizing solar panels to recharge the battery.

Conclusion

Through the engineering design process, we selected a design space from our initial problem statement and generated three design alternatives. From these, we incorporated the successful features into an initial prototype, which used weight sensors to play sound through speakers. We soon realized that the coding and circuitry involved in this setup would have been rather complicated, so we reevaluated our design and instead used buttons to light an LED. Our final design involved buttons within two cushions that light up an LED when a child is present in a car without a parent.

Using our final prototype, we were able to detect an unattended child's presence with a success rate of 96%. Despite this success, much of our design is still proof of concept for several further modifications in a marketable design, including an interactive app interface, a constant power supply, and a variable alarm delay. Our final prototype cost $57.06, but through optimizations in the creation process we estimate that manufacturers could produce this modified prototype at a cost of $27.06 per unit.

Citations

[1] http://noheatstroke.org

[2] http://www.kidsandcars.org/how-kids-get-hurt/heat-stroke/

[3] https://www.consumerreports.org/child-safety/heat-stroke-death-risk-to-children-in-hot-cars/

[4] https://www.amazon.com/KEDSUM%C2%AE-Arduino-Wireless-Bluetooth-Transceiver/dp/B0093XAV4U/ref=pd_bxgy_147_3?ie=UTF8&refRID=0D21BJE56PKAEYQYN9NB

[5] http://nypost.com/2017/06/14/10-year-old-boy-invents-device-to-prevent-hot-car-deaths/

[6] http://abcnews.go.com/US/technologies-designed-prevent-hot-car-deaths-work/story?id=479
91074

Appendices

Appendix A: *Problem Statement*

Our E4 instructors gave us the following project description, which contained a good amount of background information:

"All summer long, we hear horrible news stories of young children suffering heat stroke from being left in cars as the temperature rises. Sometimes a parent plans a short errand that runs longs – or they don't realize how the heat rises. Other times, an overtired parent simply forgets to drop off a child at child care, goes to work and forgets the child in the back seat. Either way it is traumatic and a horrific fate for both child and parent. Research the phenomenon and design a solution. It can address any aspect: keeping a parent from leaving a child in a car, alerting the parent or passerby or keeping the temperature in the car cool enough until help arrives."

We recognized that in this original project description there were several implied solutions in the last sentence: "keeping a parent from leaving a child in a car, alerting the parent or passerby, or keeping the temperature in the car cool enough until help arrives." However, since the rest of the description was intentionally left open, there were no biases or errors that we recognized. As such, we simply ignored the implied solutions when synthesizing the following initial problem statement:

"Research the phenomenon of an overtired parent forgetting their child in the back seat and design a solution."

During our next advisor meeting with Professor Orwin, we realized that this statement was too broad, since it did not actually specify a design space that we would be working in. From our research, we realized that we wanted to explore a preventative design space. Specifically, we wanted to focus on children unintentionally forgotten in car seats, as these were the children at greatest risk of heat stroke. With this design space in mind, we made our first and final revision to the problem statement:

"Create a device designed to prevent parents from forgetting their children in car seats."

Throughout the project, we referred back to this problem statement to be sure that our design iterations were fulfilling the design space we wished to explore.

Appendix B: *Work Breakdown Structure*

To make sure our time spent on the project was organized and efficient, we create a work breakdown structure. In it, we broke down our design process into our three main areas of focus: the Design process, making our Prototype, and creating our E4 Deliverables. We then broke these main areas into individual tasks, which we distributed amongst ourselves during team meetings. Our final work breakdown chart appears below:

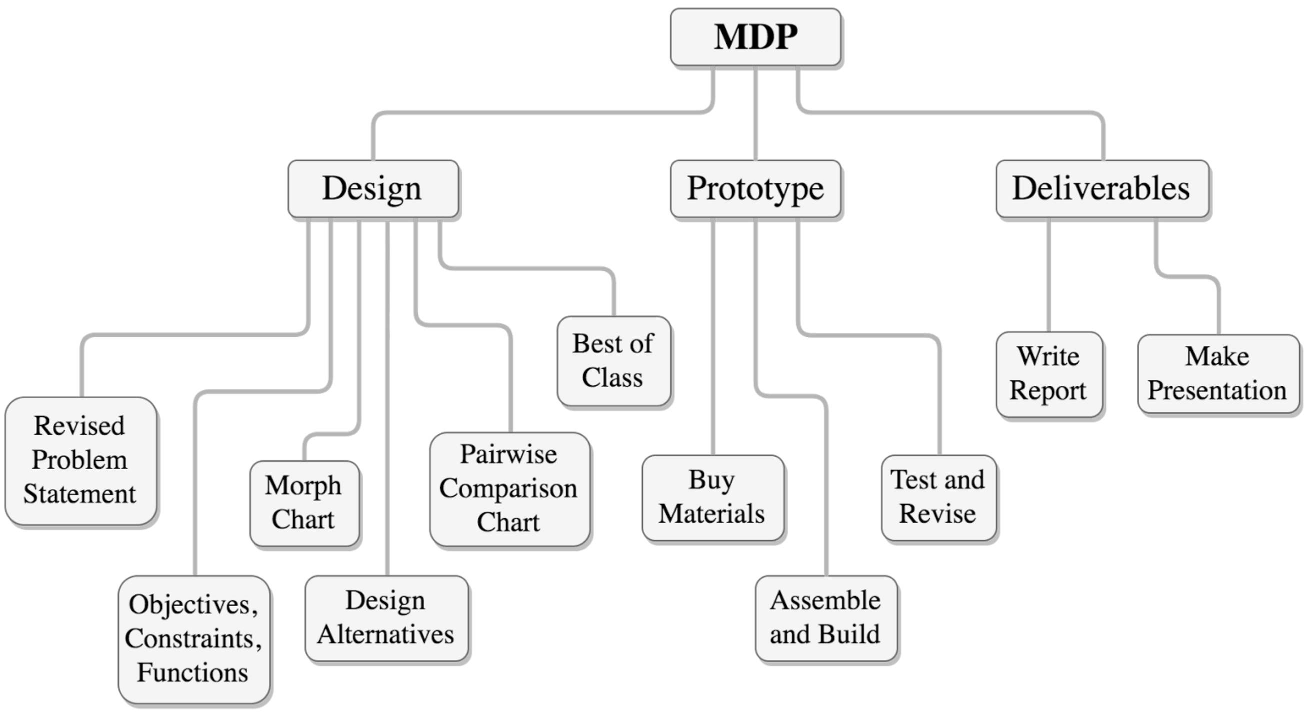


Figure A.1: *Our work breakdown structure.*

Appendix C: *Materials and Costs*

All of the materials we purchased and their prices are described in the table below.

Material	*Cost*
Arduino	$28.03
Breadboard	$3.33
Speakers	$11.98
Amplifiers	$8.55
Cushions	$20.75
Load Cells	$14.99
Buttons	$4.95*
Wires	negligible*
LED	negligible*
TOTAL:	**$92.58**

*obtained from MakerSpace

Table A.1: *All materials and respective costs*

With a total cost of $92.58, we kept within the E4 budget of $125, which was one of our constraints. We did not use all of the materials we purchased, however, so the total price of the prototype is:

$28.03 (*Arduino*) + $3.33 (*breadboard*) + $20.75 (*cushions*) + $4.95 (*buttons*) = **$57.06**.

For the final device, we can estimate a price to the customer by considering the modifications we suggest. First, we would need a continuous power source, such as a battery, so we can add about $5.00. We also recommend thin film buttons rather than the current cushions and buttons, so we can get rid of the cost of cushions, and approximate the price of the buttons to also be approximately $5.00. Finally, we would need a bluetooth module to connect to the Arduino that can then communicate with the app, which would cost $8.99[4] . The total price of the updated prototype would be about:

$5.00 (*batteries*)+$28.03 (*Arduino*)+$3.33 (*breadboard*)+$5.00 (*buttons*)+$8.99 (*bluetooth module*) = **$50.35**.

If mass produced, the Arduino would no longer be necessary, and a custom designed microcontroller with only necessary components for the device could replace it. Estimating the cost to produce this microcontroller at $5.00, which seemed reasonable from our research, would result in a streamlined manufacturing cost of:

$50.35 (*updated prototype)* - $28.03 (*Arduino)* + $5.00 (*custom microcontroller)* = **$27.32**.

Though the prototyping cost would be higher, the manufacturing cost for each device would decrease significantly. We can assume that if mass produced, the device could be sold profitably at a cost of less than $30, which would satisfy our constraint.

Appendix D: *Code References*

Arduino Code:

```
const int buttonPin1= 7;      // the number of the first pushbutton pin
const int buttonPin = 2;     // the number of the second pushbutton pin
const int ledPin =  13;      // the number of the LED pin

int buttonState = 0;         // variable for reading the pushbutton is not pressed
int buttonState1 = 0;      // variable for when the pushbutton is pressed

long time = 0; //
int timeBetweenReadings = 100;// We want a reading every 200 ms;

void setup() {
      // put your setup code here, to run once:

    pinMode(ledPin, OUTPUT); // initialize the LED as an output:
      pinMode(buttonPin, INPUT);  // initialize the first pushbutton pin as an input:
      pinMode(buttonPin1, INPUT);  // initialize the second pushbutton pin as an input:
}

void loop() {
      // read the state of the pushbutton value:
    buttonState = digitalRead(buttonPin);
      buttonState1 = digitalRead(buttonPin1);
      // check if the pushbutton is pressed.
      // if it is, the buttonState is HIGH:
      if(millis() > time + timeBetweenReadings){
      if (buttonState == HIGH) {
          if(buttonState1 == HIGH) {
              digitalWrite(ledPin, LOW);
        }
          else {
              digitalWrite(ledPin, HIGH);
          }
      }
      else {
          // turn LED off:
          digitalWrite(ledPin, LOW);
      }
      time=millis();
  }
```

Figure A.2: *Our Arduino code that receives input from two buttons and process the input to turn on the LED when appropriate.*

Plain Text Code:

```
const int buttonPin1= 7;      // the number of the first pushbutton pin
const int buttonPin = 2;     // the number of the second pushbutton pin
const int ledPin =  13;      // the number of the LED pin

int buttonState = 0;         // variable for reading the pushbutton is not pressed
int buttonState1 = 0;      // variable for when the pushbutton is pressed

long time = 0; //
int timeBetweenReadings = 100;// We want a reading every 200 ms;

void setup() {
    // put your setup code here, to run once:

  pinMode(ledPin, OUTPUT); // initialize the LED as an output:
    pinMode(buttonPin, INPUT);  // initialize the first pushbutton pin as an input:
    pinMode(buttonPin1, INPUT);  // initialize the second pushbutton pin as an input:
}

void loop() {
    // read the state of the pushbutton value:
  buttonState = digitalRead(buttonPin);
    buttonState1 = digitalRead(buttonPin1);
    // check if the pushbutton is pressed.
    // if it is, the buttonState is HIGH:
    if(millis() > time + timeBetweenReadings){
    if (buttonState == HIGH) {
       if(buttonState1 == HIGH) {
          digitalWrite(ledPin, LOW);
      }
       else {
          digitalWrite(ledPin, HIGH);
       }
    }
    else {
       // turn LED off:
       digitalWrite(ledPin, LOW);
    }
    time=millis();
 }
```