HeatHunt - the Warm and Cold Navigation Tool

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1 ABSTRACT

Navigation in museums today is aided through guided tours, digital maps, and booklets. All these modes of navigation can sometimes be complex to understand and may lack immersive interactions. This paper introduces 'HeatHunt', a temperature-regulated device with the goal of gamifying navigation. Current approaches to making museum exploration more interactive include the use of audio-visual aids, tactile stimulations, and navigation applications. 'HeatHunt' aims to elevate visitors' navigation experience by gamifying the navigation process and making it more enjoyable.

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'HeatHunt' - taking inspiration from the children's classic Hot and Cold game - is a handheld cuboid that heats up when on the correct path but cools down as you deviate from it. It aims to enrich visitors' museum experiences.

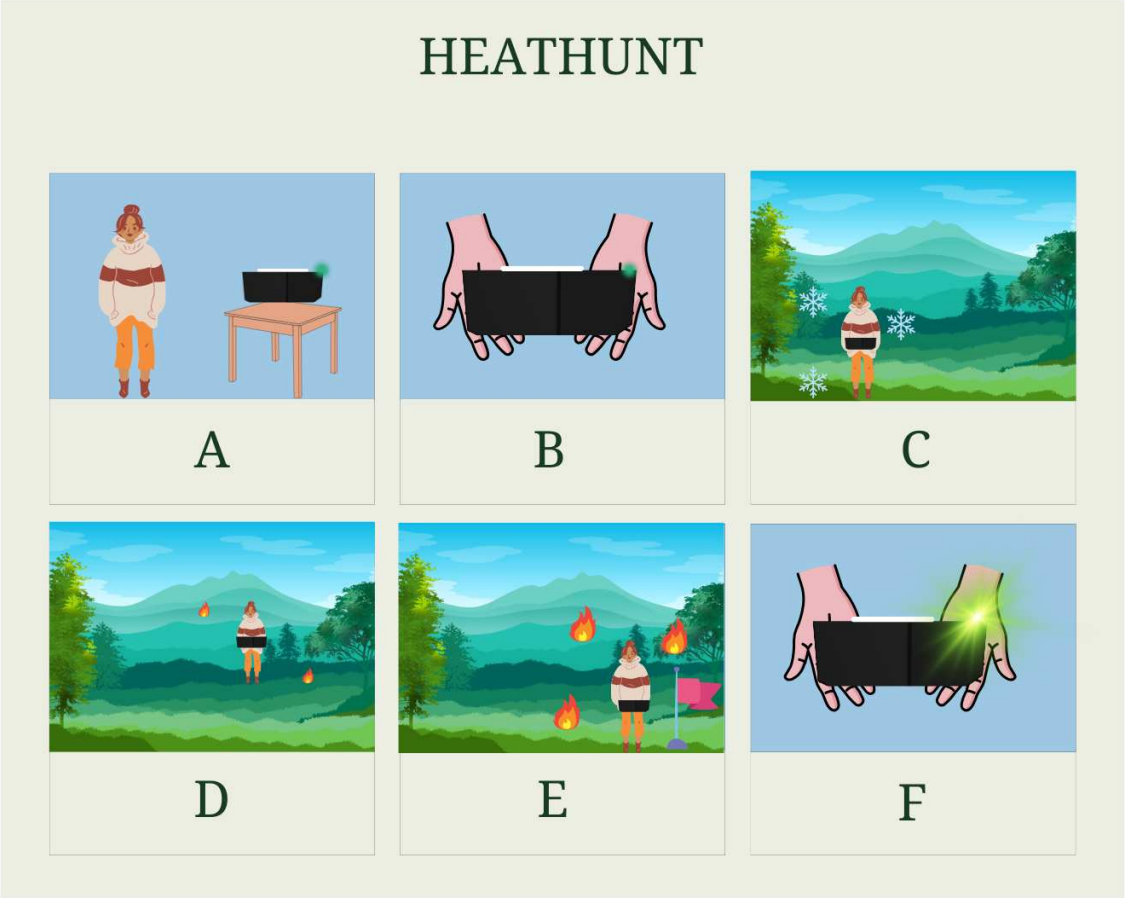

Fig. 1. **A-** Mary is visiting her town's open exhibit about industrial heritage sites. **B-**She uses HeatHunt for her exploratory journey. **C-**Mary knows she is far away from a hidden spot she wanted to visit because HeatHunt's plate is cold.**D-**She moves around and allows the plate's temperature to guide her. **E-** As she feels it getting warmer, she knows she has almost reached! **F-** The green light turns on, and Mary finds herself at the hidden spot!

2 INTRODUCTION

HCI and design researchers have been seeking different ways to increase museum engagement and retain relevance. This project aims to contribute towards this idea[1–3].

Some common approaches to enriching visitor experiences include the use of audio, visual, and tactile-based aids. Though each of these is very beneficial for supplementing visitor experiences, they prove to have some limitations. Audio-based guides are an excellent solution for helping the visually impaired, are available in different languages, and are portable, but they may present challenges due to hygiene issues that arise from the usage of devices like

headphones[2]. Visual guides in museums include signs, colour-coded paths, and display monitors[4]. These are beneficial as they convey a large amount of information, although they may cause sensory overload issues[5–7]. Tactile guides may need constant maintenance and have space constraints, although they are unique, boost engagement, and create an immersive experience[3, 8].

HeatHunt's versatility helps in mitigating the limitations that may arise, as noted above. HeatHunt is not susceptible to language barriers or maintenance issues due to its simple design and robust material. It is relatively inclusive and can be enjoyed by everyone. Moreover, as noted by multiple participants in Study 2, it does not have a learning curve and is quite intuitive. Participants in Study 2 noted that it overcomes any sensory overload issues.

HeatHunt aims to bring innovation to the experience of visiting museums by gamifying navigation. It guides visitors through the museum using a temperature stimulus by heating up while on a path towards the destination and cooling down as the visitor deviates from it. The path to the destination is calculated using the Haversine formula. The cube's temperature is adjusted using a Peltier. The cube locates the visitor's real-time position using global positioning system (GPS) modules. The cube's material is chosen by keeping robustness and durability in mind for protection against accidental falls. HeatHunt's circuit consists of a GPS module, a Peltier, an Arduino board, and four batteries.

Overall, HeatHunt endeavours to contribute to the space of cultural exploration by attempting to address certain limitations associated with conventional museum immersive devices. Studies 1 and 2 are testaments to this.

Fig. 2. Final Implementation

3 RELATED WORK

This section will provide an analysis of conventional navigation methods and delve into their inherent limitations. Furthermore, we will compare these techniques with the recent digital tools to demonstrate the unique features of the HeatHunt.

3.1 Insights of Conventional Navigation Techniques and Modern Digital Tools

In the context of tourism, there are several traditional navigation strategies available with distinctive traits. The combination of paper maps and fixed signage is one of the most standard options that can be efficiently duplicated in large

amounts[9]. Paper maps are more portable for visitors to carry with them and immediately gain an overview of the entire tour area. Signage, on the other hand, can support tourists in recognising directions and destinations. Both these two approaches are static in nature which means once they are produced, it becomes challenging to update information such as temporarily closed pathways due to construction or exhibition areas that are currently inaccessible. On top of that, these preset navigation, limit the capability to offer visitors real-time positions or personalised information[10]. It is noteworthy to mention that maps require visitors to interpret their location using two-dimensional representations, which can be tedious and tricky for certain persons[11].

The integration of new technologies into navigation is a prominent trend, which has led to the emergence of digital guide tools. Augmented Reality(AR) and Virtual Reality(VR) are representative innovations when it comes to the area of navigation. They provide immersive experiences that are significantly distinct from the traditional methods previously mentioned by enhancing the real-world environment by adding digital overlays and providing location information in various visual and audio formats[1]. However, the implementation of augmented reality and virtual reality in the tour process does not come without difficulties. The expenses arising from the development and regular maintenance of the corresponding software can be overly expensive, along with the distribution of dedicated equipment. This could be a substantial challenge for many organisations. Additionally, the utilization of these technologies often calls for the use of advanced devices, and usage beyond a certain duration may cause discomfort in users[12]. This greatly restricts the range of applications for these tools.

3.2 The Role of Sensory in Modern Navigation Systems

The deployment of human sensory inputs such as touch, visual, and auditory into navigation system has become increasingly common in recent years across several fields. The motivation behind this trend is to optimise user engagement during the navigation process and provide visitors with a more intuitive and entertaining positioning experience[13].

The utilisation of temperature variations on device surfaces that may be touched to convey information or direction indication is a technique that exploits users' tactile perception. Temperature, as a fundamental sensory input, usually triggers spontaneous and immediate reactions in humans to cold or warm[14]. Moreover, temperature, a non-visual method of conveying information, usually carries a more significant role in restricted environments, especially under circumstances of low visibility or involving individuals with visual impairments[15]. Humans have an innate ability to respond to changes in temperature, and this instinctive reaction is highly effective for navigation without requiring any previous training or adaptation. Temperature also holds emotional meaning for many people through sensations of warmth and coolness[14]. The feedback based on temperature changes is continuous, which offers a more nuanced experience. The unique benefits of this approach are introduced by applying touch to transmit signals so that users can get directed without constantly monitoring the devices. As a result, visitors could pay more attention to the surroundings within the tour area, which increases the immersive quality of the experience.

Visual communication is a common and effective way of presenting information with the involvement of elements like colours and signage to help people understand their current location. The fact that the visual factor is the primary and popular sensory modality of human beings makes it feasible for the immediate transmission of navigational cues[4]. On top of that, the merge of visual clues and artistic design enables creative decorations that align with the presentation theme.

Auditory navigation normally consists of audio signals, voice commands, music, and other sound effects to help visitors reach their destinations or obtain information about the event. Background music and sound effects not only

deliver practical details but also form the overall atmosphere that encourages the integration between visitors and tour settings. Additionally, auditory is particularly effective in situations where visual attention is needed elsewhere. The extra contextual information from the auditory helps visitors' understanding of the trip.

The integration of human senses comes with advantages from various perspectives. Sensory-based navigation is adaptable to humans' fundamental sensory habits, which overcomes the boundaries of languages and education[13].

Users can process directional indications at a more instinctual level, reducing the need to interpret complex visual maps. This demonstrates the universal applicability and inclusiveness of sensory-based navigation, making it an optimal tool for diverse populations, especially in multicultural and multilingual public settings such as exhibitions. Additionally, sensory-based systems can improve accessibility by addressing the requirements of a range of users, including individuals with visual or auditory impairments. For instance, tactile feedback can offer efficient hints for people with visual disabilities, while auditory suggestions may assist those who are unable to read conventional signs or digital displays.

3.3 HeatHunt: Bridging the gap

Our cube-shaped device, HeatHunt, has the ability to address some limitations of conventional and digital navigation methods above. The dynamic and interactive navigation provided by HeatHunt is distinct from paper maps and signage. It helps users navigate to the preset destination with the exploitation of thermal feedback and conveys the distance between visitors and exhibitions in an intuitive way. 92.8% of the participants agreed on HeatHunt's accessibility in our Study 2. The methodology of temperature indication is understood by people of all age groups and cognitive abilities. As well, this material is more robust against glitches compared to delicate electronic components.

In comparison to digital navigation tools including AR and VR, HeatHunt does not rely on a continuous internet connection, demonstrating its resilience across multiple environmental circumstances and retaining the basic functionality on a wider scope. Meanwhile, the cost-effectiveness of developing and maintaining HeatHunt is a considerable benefit. Navigation with AR and VR typically demands a major financial investment in dedicated visual data and could involve professional hardware[12, 16]. However, the utilisation of GPS technology is not dependent on regular software updates or maintenance[17]. The implementation of solid physical components reduces the operational costs greatly. Our design also presents excellent versatility when it comes to adapting to different exhibition areas, as evidenced in our interviews in Study 2. While digital tools normally require substantial modifications to their entire assets in the event that navigation content changes, HeatHunt can update its destination through a code update to the GPS settings to cope with shifts in exhibition layouts or the addition of new displays. This flexibility not only makes our device more suitable for a wide range of showcases, but also saves the time and effort needed to patch up the navigation systems.

In summary, our HeatHunt offers a robust, affordable, and flexible design that overcomes the limitations found in existing navigation systems. It delivers a user-friendly and reliable option that can improve visitor experiences in multiple settings, efficiently attracting and guiding visitors.

4 USER GATHERING DATA

The objective of our preliminary study was to gather participant feedback about the idea of having an interactive navigation experience at museums. Our primary areas of focus included:

- Participant's general attitudes towards having a navigation system in museums
- Correlation of museums and respondents.

- Participant's views on the hot and cold game analogy.
- Participant's responses about the shape and temperature range of the idea

Acquiring this data helped us gain a better understanding of our user base and the expectations of the device, which enabled us to refine HeatHunt's design to allow for a more immersive experience.

4.1 Participants

For our questionnaire, we had 53 responses, of which 23 were female, 26 were male, and 4 were non-binary. We had 10 responses from those under the age of 18, 25 from 18-25, 9 from 26-45, 7 from 46-65, and 2 from over 65.

4.2 Questionnaire Design

Our preferred data collection method was an online questionnaire because of its flexibility toward respondents and its ability to gather a geographically large and diverse participant response base. We were able to yield valuable insights into user preferences for HeatHunt's designs. HeatHunt aims to provide an immersive experience for visitors at museums, which could be influenced by factors like age, gender, and companions. By using a questionnaire, we were able to get anonymous, unbiased responses from participants. The questionnaire was designed to understand various aspects of the user base, including:

4.2.1 General attitudes towards having a navigation system in museums. Participants were asked about their views on the usefulness of this device in museums. They were asked if they thought this navigator device would enhance their museum experiences, what potential benefits they saw to introducing this device in museums, and if they had any concerns they wanted to highlight.

The question aimed to ensure a user-centred design, proactive risk mitigation early on in the designing stages, and to ensure continuous iteration in product development.

4.2.2 Correlation of museums and respondents. Participants were asked about how frequently they went to the museum. They were given the following parameters to choose from - daily, weekly, monthly, seasonally, yearly, and never. They were also questioned about their companion preferences for museum visits.

4.2.3 Participant's views on the hot and cold game analogy. Using a 5-point Likert scale, ranging from "not familiar interesting" to "very interesting", respondents rated what they thought about using the hot and cold game analogy in an interactive device at museums.

4.2.4 Views on the shape and temperature range of the idea. Collecting data about the shape of the device and the temperature ranges users thought they would be comfortable handling for long durations of time. Participants voiced their suggestions either by suggesting a device form they thought would work best or by picking one of the three forms we suggested, i.e., wristband, a cube, or a glove. To gauge what an appropriate temperature range would be, we asked participants if they would be comfortable wearing a device with temperature fluctuations between the range of 10 and 40 degree Celsius and were prompted to respond with a yes, no, or maybe.

4.3 Results

In this study, we analysed the general attitudes and overall proclivity of 53 respondents towards the features and aims of our navigation device aimed at enhancing museum experiences. Below, we outline a summary of our findings

that will influence the design of HeatHunt, followed by a discussion. Overall, the data points towards participants having a generally enthusiastic perception of this navigation device. They believe it will provide an enhanced museum experience and are comfortable with the different features of this device.

4.3.1 Participant's general attitudes towards having a navigation system in museums.

A notable 69.8% of participants were positive that this device would enhance visitors' experiences in museums; 26.4% were unsure about how beneficial this device would be; and 3.7% of participant thought that this device would not have a favourable outcome.

We listed three possible ways our navigation device might be valuable in enhancing museum navigation and asked participants to choose one or more options. 67.9% of participants selected the option which said "customised tours based on visitor interests," 81% selected "interactive experiences", and 60.3% selected "enhanced navigation through exhibits."

Fig. 3. User feedback

Participants were also asked about any possible concerns they could identify while they would interact with this device in a museum. When answering this question, 7% respondents were concerned with the data storage of their information; one respondent was particularly apprehensive about the process for data storage after their museum visit was completed, while 3% were concerned with the temperature fluctuation feature of the device. One respondent thought that this device would be more complex than using the current methods of navigation, and another thought that the immersive experience offered by this device might cause distractions and visitors' might potentially miss out on other exhibits. One respondent suggested spontaneity of navigation as a possible concern. 10% respondents voiced hygiene concerns regarding this device since many people would come in contact with it throughout the day.

4.3.2 Correlation of museums and respondents.

Frequency of museum visits. A total of 49% of participants responded that they visit the museums seasonally. This was followed by 20.7% who visit monthly and 18.8% who visit annually. 3.7% responded that they visit museums weekly and 7.5% responded that they never visit museums.

Companion preferences. When asked about who they enjoy going to museums with, a vast majority (60.3%) mention that they enjoy going with friends and family. Surprisingly, 13 participants mentioned that they enjoy going to museums alone. 7.5% of the respondents responded that they enjoy having their colleagues' company at museums.

This data helped us understand our user base better and modify our device to better cater to this audience.

4.3.3 Participant's views on the hot and cold game analogy.

A vast majority of the respondents (85%) found the idea to be very or somewhat interesting. 11% of the respondents were neutral about using such an interactive device during their museum visits. Only 3.8% of respondents found the

idea to be “not very interesting.” This reaffirmed our discussion to correlate the device with a pre-existing game that is popular among users.

4.3.4 *Views on the shape and temperature range of the idea.*

A significant portion of the respondents, i.e., 66%, agreed that the most suitable device would be one in the form of a cube, while 30% considered the device to be more comfortable as a wristband. Only 3.7% of respondents considered a device in the form of a glove to be appropriate, and no respondent chose to specify a completely different device form from the options given, though we had allowed them to do so.

Fig. 4. Device Form

42% of respondents perceived the given temperature range of 10-40 degree Celsius as appropriate for comfortable use; a close 37.7% were not sure and chose the option ‘maybe’ as a response to this question; and 20% believed that this temperature range would in fact not be suitable for human skin.

5 DESIGN AND IMPLEMENTATION

HeatHunt is a handheld cuboid with four external components: a Peltier module, an LED light, an antenna, and a carry handle. The Peltier is attached to the top face of the device, and the carry handle is on one of the faces on the side. The LED light is fixed to the lid of the device, and the antenna sticks out of the top. The user of the device would place one hand at the top of the device, over the Peltier module, to sense temperature changes, and the other to hold the device steadily. The internal circuitry of the cube consists of a battery, a H-Bridge, a GPS module, a Peltier, an LED light, and an Arduino board. To provide an unambiguous indication that the user has successfully navigated to their location, the LED light turns on as the GPS module senses that the user’s coordinates match those of the entered location.

HeatHunt’s attributes like shape, size, material, and temperature range were adapted into their current states with Study 1 as a guide. We opted for PLA (Polylactic Acid) as the material for building the cuboid as it possesses several advantageous characteristics. It is a material that is light yet robust, which would ensure users would be comfortable holding it for long periods while navigating around the museum. PLA can withstand temperatures up to 60 degree Celsius, making it a suitable choice for our device, as the Peltier module is programmed to fluctuate between the 10-40 degree Celsius temperature range[18]. PLA also has the very beneficial quality of being antibacterial[19] so it requires minimal hygiene maintenance. It is also able to withstand impact and general wear and tear. This attribute was particularly important, as this device would be in contact with multiple visitors everyday.Furthermore, PLA was readily accessible to us and was an inexpensive choice for 3D printing. All these characteristics made it a very appropriate choice for our project.

We track the user's location using a GPS module with an antenna. The specific model that we have used is the Adafruit Ultimate GPS Breakout v3. Then, we uploaded code to the Arduino board to enable it to read and process data from the GPS module circuit, including latitude, longitude, time, date, angle, speed, and satellite number. Due to the high volume of data transmitted by the GPS module, we used a sensor library (adafruit.h) to filter out the useful information needed for our device.

Once the GPS module locates the user's position, it calculates the distance to the user's destination using the Haversine formula[20]. The Peltier module is programmed to reflect this change in distance via a temperature change accordingly using a linear mapping function that maps the distance to a potency value given to the Peltier. It is able to do so with the help of an H-Bridge, which regulates voltage to the Peltier. The Peltier then increases or decreases its temperature by 1 degree celsius for every change of 3 metres towards or away from the destination, respectively (the change of 1°C per 3 metres is using a distance range of 100m). The Peltier module's model used in our circuit is the MikroElektronika Peltier Module, 57W, 6.4A, 14.4V.

As a final step to improve usability, we added a green LED light and a carry handle. The LED would light up when the user successfully navigated to the location entered into the device. This was done to remove any ambiguity regarding the maximum temperature the device would reach and to clearly communicate to the users that they had arrived at the final destination. The carry handle was added keeping object affordances in mind. It also serves as a feature to mitigate situations where a user might not want to be in prolonged contact with the Peltier.

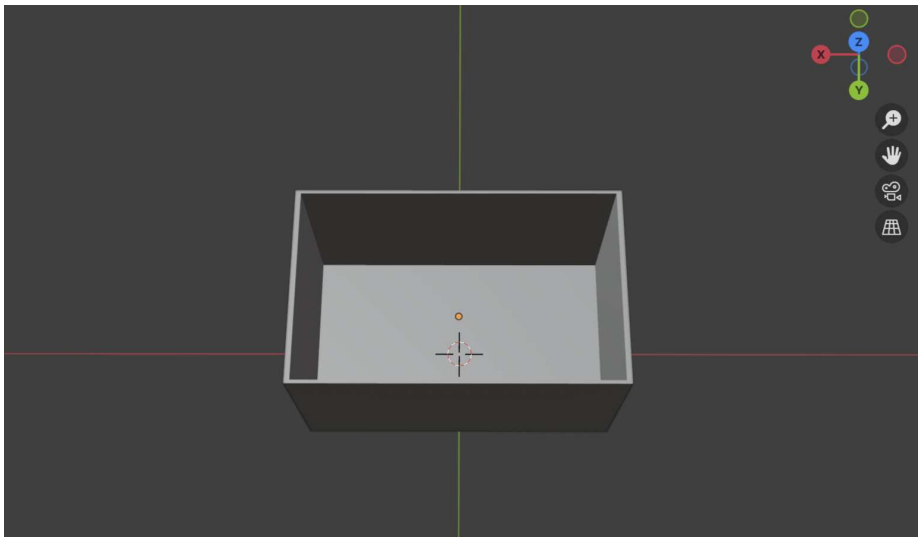

Fig. 5. 3D model of our device

The attributes of HeatHunt are:

- **Shape** - As noted from the responses of Study 1, most of the participants responded that they prefer a cube, and so we went ahead with that. However, after multiple iterations of implementing the internal circuitry, we found the need to modify the device to a cuboid shape for a better fit.

- **Size** - Participants in the study indicated they would feel more at ease while handling a device that was easy to carry around. The measurements of 20cm, 9cm, and 10cm (length, width, and height, respectively) were adopted after several iterations of the choice and placement of the internal components of the device.
- **Material** - The material selected for the body of HeatHunt is PLA (Polylactic Acid).
- **Temperature Fluctuation** - The temperature range for HeatHunt is between 10 and 40 degree Celsuis which is achieved with the help of the Peltier. Results from Study 1 supported this decision.
- **Real-time Location Tracking**- To allow for real-time location tracking of the users, HeatHunt has a GPS module implemented in this. We used an antenna to enhance GPS signals.
- **Visual Stimulus** - HeatHunt signals to its users on arrival at the destination by lighting up a green LED.
- **Anti-Slip Mechanism** - In order to prevent accidental slippage of the HeatHunt, there is an anti-slip carry handle. This also facilitates easier holdage.

5.1 Design Iterations

When initially planning for the HeatHunt, we considered some different shapes for its design. We considered making it as a wristband or a glove that could be worn. But from our preliminary studies, we found that most people preferred a cube shape, leading us to proceed with the same.

As HeatHunt's primary objective is to gamify navigation, we ensured that we carefully considered all the navigation module options. Initially, we thought of implementing navigation using Radio-Frequency Identification (RFID) tags and readers. Though attaching an RFID tag to the device was feasible, in order for the device to sense whether the user was on the right path or not, the user would have to be within a few metres of the RFID readers. We attempted implementing a 'checkpoint' feature, where the user would have to tap the device at each checkpoint on their path to record their location. However, we decided against this feature mainly due to two reasons. Firstly, adding checkpoints would mean equipping each device with an RFID tag and each checkpoint with an RFID reader. This was not economical. Secondly, implementing this feature did not seem to enhance the visitor experience at the museum in any meaningful way - which was the primary objective of our project. The GPS module failed to pick up a signal indoors. In an attempt to overcome this problem, we tested adding two different antennas, but neither seemed to help with the GPS's signal strength indoors. However, one antenna significantly improved the strength of the GPS module outdoors, leading us to include it in the device's circuitry.

Over the duration of the testing phase, we had several iterations with the electrical components, which we changed to improve the efficiency and portability of the device. Initially, we had an Arduino board with a simple circuit with only a Peltier and a H-Bridge to help us distribute the current between the Peltier and the Arduino so that it didn't get overstimulated. We tested to see the speed of temperature change and what would be a stable power supply source. We then added a potentiometer to the circuit above to have a way of controlling the heat generated without changing the power supply and performed a series of stress tests, like the Peltier's prolonged use and rapid temperature changes, to evaluate the Peltier's suitability. All these iterations were performed with the circuit receiving power from a desktop power supply. The next logical step was to configure a power supply based on batteries so we could have a portable device, something necessary if we want people to carry our device. So once a parallel configuration of batteries in series was added, we were able to make the circuit portable. We added two 9V batteries in series for the circuit and one 9V for the Arduino board. Finally we tested the GPS module on its own to see the messages it sends to the Arduino board and then to filter it so we only received the messages we needed. After the filtering was done, the GPS module was included in the main circuit and by updating the code we could now control the heat produced by the Peltier depending

on the distance between the player and the destination, since this was the method of controlling the temperature the potentiometer was removed from the circuit. As a final step a LED light was included to signal the arrival to the destination.

6 DEVICE EVALUATION - STUDY 2

To gain a better understanding of the user feedback and interactions while using HeatHunt, we conducted another user study. In this study, the participants were asked to perform an activity that would test out the workings of HeatHunt in a museum-like environment.

6.1 Participants

We recruited 14 university students, out of whom 8 were male and 6 were females, to take part in this study. Nine of these participants were recruited using convenience sampling, and the other five using snowball sampling. This participant pool was a diverse sample of museum visitors, ranging from avid museum visitors to occasional visitors. All participants were in the age group of 18-30 years.

After conducting an initial study analysis with these fourteen participants, in order to further understand how HeatHunt could be incorporated into museums, we interviewed four participants from the fourteen. We decided to perform this interview on the basis of stratified sampling so that we could better understand the usage of HeatHunt for exploratory navigation from the point of view of avid visitors.

6.2 Study design

We conducted our study by allowing the participants to navigate to a location using HeatHunt for 2 minutes. Following this, they were asked to fill out a questionnaire describing their experience and feedback in detail. We conducted this activity in an open and busy environment. The reasoning behind this was twofold. Our first reason was a technical one in that our GPS could only pick up a signal outdoors. The second reason was to be able to position users in an environment that mirrors the environment where HeatHunt is proposed to be used, i.e., like an open air exhibit. Moreover, an open area allowed users to solely use HeatHunt's temperature fluctuation to guide them to the destination, unlike conventional museum navigation methods.

6.2.1 Navigation using HeatHunt: We divided our testing phase across three days to ensure all participants had enough time to interact and engage with HeatHunt. On days one and two, we performed the activity with five participants, and with four participants on the third day.

Users were asked to navigate to an undisclosed location in Royal Fort Gardens while holding HeatHunt and decoding the temperature cues. The users were explained the basic workings of the device i.e. the temperature increasing meant they were closer to their destination, and a decrease in the temperature meant they had moved further away. After this explanation, the users were prompted to rely on their instincts and received no guidance from the team. This helped in getting a more accurate representation of how a user would engage with HeatHunt while navigating to a location without our biases involved.

6.2.2 Questionnaire design: The questions in this questionnaire designed for Study 2 were qualitative in nature. We had nine questions that encouraged users to describe their feedback and opinions with regard to HeatHunt in detail. The questions aimed to determine:

- Immersive and engagement qualities of the device, using a 5-point Likert scale with options ranging from “Very Poor “ to “Very Good”.
- How fun participants found the activity to be, using a 5-point Likert scale with options ranging from “Very Boring “ to “Very Fun”.
- Whether participants found it easy and intuitive to use, using a 5-point Likert scale with options ranging from “Not at all easy “ to “Very Easy”.
- How likely were participants to visit a museum or an exhibit that employs HeatHunt, using a 5-point Likert scale with options ranging from “Very Unlikely “ to “Very Likely”.
- What aspect of HeatHunt they found was the most enjoyable in the form of a couple of sentences.
- Their opinions about HeatHunt’s temperature range in a textual format.
- If they enjoyed the use of a temperature stimulus in a few words.
- If they would have preferred to have known the location they were navigating to or if they liked the suspense associated with having an undisclosed location.
- If they found the device easy to follow because it used a single sensory stimulus.

6.2.3 Further Feedback using Interviews. To understand the views of avid museum visitors about the use of HeatHunt in museum exhibits, we conducted one-on-one interviews with four of our participants. Below are the six questions that enabled us to gain the most insight into the users’ experience during the navigation activity.

- What did you feel like when using HeatHunt?
- What were your first opinions about the device before using it?
- Did your opinions change after using it? If yes, how?
- How would you feel about incorporating this device in your favourite museum?
- Does the concept of this device feel personal to you?
- What qualities do you think HeatHunt has that separates it from other navigation devices?

6.3 Results

6.3.1 Immersive and engagement qualities of the device.
21.4% of the participants found the immersive qualities to be “very good,” 57.1% found it to be “good,” and 21.4% found it at an acceptable standard. 28.6% of the participants found the device to be very good on its quality of engagement, while 57.1% found this to be “good” and 14.3% found it to be acceptable.

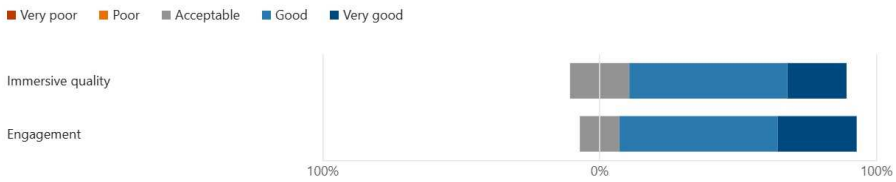

Fig. 6. Feedback - Quality of using HeatHunt

6.3.2 HeatHunt’s ’fun’ aspect.
An equal proportion of 35.7% of the participants found the activity “very fun” and “fun”, and 28.6% found it to be “okay”.

6.3.3 Level of ease and intuitiveness: 57.1% of the respondents found the device easy and intuitive to use. This was followed by 35.7% who found it very easy, and only 7.1% found it somewhat easy.

Fig. 7. Feedback - Is it easy to use

6.3.4 Likelihood of visiting a museum that employs HeatHunt.
64.3% of the participants said that they are very likely to go to museums that employ HeatHunt. It was followed by 28.6% who said that they are somewhat likely to go to such a museum. Only one of the participants responded that they are somewhat unlikely to go to such a museum.

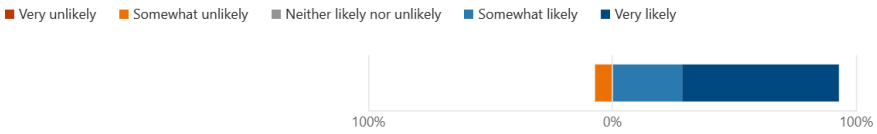

Fig. 8. Feedback-Will you visit a museum that employs HeatHunt

6.3.5 Aspect they found most enjoyable.
Two participants appreciated the decision to have an undisclosed location, saying, “The fact I found most enjoyable was being guided without knowing my destination by a cube as it gave a sense of mystery” and “Having an undisclosed location and having something to look forward to during a boring museum visit”. One participant was amazed by how the device was able to translate geographical distance information by changing the temperature.Three participants found the resemblance to the game of Hot and Cold the most enjoyable.

6.3.6 Opinions on the temperature range.
One participant found the temperature range to be “quite appealing.” One participant said that the temperature range was “perfect,” and another said that it was “just about right.” One respondent suggested that “a much higher temperature could be used to signal that we’ve reached the destination.” For this question, five of the respondents seem to have misunderstood the question, and so these responses were eliminated due to irrelevance. If they enjoyed the temperature stimulus: 64% responded with “Yes”, 1 respondent said this was unique, and 1 respondent said this was a “creative way.”

6.3.7 Destination preferences.
78% of the participants preferred having an undisclosed location that they had to navigate to, while 2 participants preferred the alternate.

6.3.8 *Opinions on having one sensory stimulus.*

12 of the 14 participants said that they found it very easy to navigate through the museum using HeatHunt as it has a single sensory stimulus. One of the participants said that they felt it was easy to use as it didn't put them in "sensory overload". Another said, "It doesn't make me feel overwhelmed as most museums do with their vast amount of information."

6.4 Results drawn from the Interview

We found that in this segment of feedback, most opinions were common and repetitive. One of the participants reminisced about their "fond memories from my childhood. Another said that they would really love going to a museum where they would have the "opportunity to relive their childhood through HeatHunt. One participant wondered how a simple box could prove fruitful in enhancing museum experiences, but was pleasantly surprised after this activity and thought it would be a "delightful little addition to her museum visits." Another participant could not find the relevance of the hot and cold analogy in a museum but found it could be a "crucial aspect in helping me find a new rare painting to obsess over this summer." One respondent couldn't wait to "whisk through the National Portrait Gallery holding HeatHunt in my hand!". When asked how HeatHunt was different from other navigation devices, some common answers were, "Personally, I didn't think I would grasp the logic of how to use it as quickly as I did," "I can't think of anybody in my family who wouldn't be able to use this," and "It's just so fun."

7 DISCUSSION

The development and assessment of our cubed-shaped device substantially augment the experience of visitors at outdoor exhibitions and expand the scope of interactive technology implementations within the context of cultural tourism. This discussion incorporates the key findings from our project, evaluates the benefits and constraints of the technology, and considers prospective options for future improvements. Furthermore, it provides an introspective analysis of the project's methodology.

7.1 Key Findings

Our initiative aims to develop a novel approach for visitors to navigate and engage with outdoor exhibitions that diverges from conventional maps and online guides. According Study 2 which we collected from our users, they also expressed our HeatHunt's validity with regard to immersion and enjoyment.

This device utilises GPS (Global Positioning System) technology to accurately capture the current positions of visitors in real-time. By combining a Peltier component that regulates the temperature on the surface, we introduce a new navigation approach that relies on temperature.

The HeatHunt significantly increases visitors' enthusiasm and engagement during exploration, according to the results of our user study above. HeatHunt offers intuitive navigation signals while encouraging people to interact with the environment along the way. These findings demonstrate that its design has reached our initial purpose by incorporating interactive technologies to provide better guidance for routes. Furthermore, HeatHunt received positive feedback around efficacy and intuition in utilising human senses.

7.2 Advantages and Limitations

The exploitation of sensory feedback introduces a distinctive thermal dimension to the indicators of guidance. This convenient method improves visitors' involvement and satisfaction during their exploration of the exhibition area.

However, feedback from the study has also brought attention to certain constraints of HeatHunt. In some extreme weather conditions, relying on temperature as a navigational indicator may be less reliable, and there is a possibility that users are not able to get a sense of whether it is warm or cold. This can potentially compromise the robustness of Heathunt in outdoor environments.

7.3 Future Improvement

To address the constraints mentioned previously as well as enhance the applicability of the device, we have proposed several directions for future upgrades. Integrating technologies like Bluetooth and RFID into the device would improve the precision of HeatHunt's positioning ability, especially in circumstances with weak GPS signals. In addition, expanding the device into multiple shapes would allow HeatHunt to adapt to a variety of environments more effectively. Expanding its functionality to offer a curated selection of destinations, tailored to their interests, would also be a key improvement. At the moment, only one location can be navigated without a code update. With the above improvement, users would be able to choose from a 'playlist of destinations' with topics like art, history, or music. Currently, the circuit operates on open-loop control. As another improvement, we aim to control the temperature and make it changes linear by adjusting the flow of the current by implementing a closed-loop circuit. We would do this by using a temperature sensor to ascertain the temperature of the Peltier and use it as the input for the Arduino to control the current flow into the Peltier.

7.4 Reflections

This project offered a unique learning experience for us, giving us essential knowledge on the creation and use of interactive technologies that are becoming more and more popular. During the project, we actively participated in the process of formulating a solution that tackles a certain need and iteratively developed it froma prototype. Every study that we conducted has reinforced the importance of user feedback in the development of an efficient and user-friendly product. Along with that, this project emphasised the concept of user-centred design, developing our ability to present practical solutions for real-world issues in the future.

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A TEAMWORK DIVERSITY/INCLUSIVITY WORK

To satisfy the various communication preferences of all members, we used multiple platforms to discuss, including Microsoft Teams, email, WhatsApp. and in-person meetings. This approach offered everyone the ability to express their opinions and participate in discussions in the most effective way.

We carried out meetings whenever there was a need to update or iterate on our product designs, besides the weekly scheduled meetings in Wednesday labs. During the decision-making phase of our project, we made an effort to achieve consensus rather than simply following the rule of majority so that the ideas of all members were respected and heard. Furthermore, it ensured that we were all at the same stage with our project progress.

For each member's brainstorm, we positively engaged in investigating the feasibility of the idea and its applicability to our project. We also respected individual preferences in assigning tasks and made the responsibilities clear with reasonable deadlines. Every team member could keep up with the overall project's progress with this mechanic.

B PRODUCT VIDEO LINK

HeatHunt's original video link with better quality