ITea – The Intelligent Tea Brewing Assistant (Team 8)

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ABSTRACT

Tea is one of the most popular beverages around the globe and the trend is rising due to expected benefits in physical health and mindfulness. But sometimes, the delicate process of brewing tea correctly can stand in the way of the desired relaxation. Depending on the type of tea and current infusion, variables like water temperature, water to leaves ratio, and steeping time can highly influence the flavor and stimulating effect of tea. Implementing the right configuration can be demanding, especially for unexperienced or distracted consumers, and often involves multiple kitchen helpers, like a manual thermometer or alarm clock.

To ease the mind of conscientious tea brewers and to remove barriers for beginners, we built a tea brewing assistant with the name "ITea". The system has the following goals:

1. Saving and simplifying of the tea brewing instructions
2. Automatization of timers in line with the brewing instructions and temperature
3. Signaling when the tea has a good temperature to be consumed

With the help of NFC cards attached to the tea boxes, the device gives the user easy instructions for every step of the tea brewing process. This device assists consumers, while still letting the user in control and limiting hygiene issues – in contrast to fully automated machines.

1 Introduction

Drinking tea as a morning routine, during a work break, or with a piece of cake is a worldwide phenomenon. In 2021 the average German consumed 71.5 liters tea, and the trend is rising (Manon, 2022). Some reasons for the momentary increase in popularity are expected benefits in physical health (Sharma et al., 2007), and mindfulness. Nowadays, the term tea includes both caffeinated and non-caffeinated hot (or cold) beverages, which are prepared by pouring (hot) water over herbs. The exact procedure of tea preparation highly varies depending on tradition, preference, and tea variant. Often, the package includes an instruction, including the following variables: water temperature, a water to leaves ratio, and steeping time. While fruit tea can steep for a long time and needs boiling water, the preparation of green and black tea is more delicate. Steeping them with water of incorrect temperature or for too long can influence the flavor and the stimulating effect. Figure 1 from Fernando & Soysa (2015) displays how fast the different substances in green and black tea change in the first minutes of steeping. Therefore, the intended mindful and relaxing act of brewing tea can quickly result in stressing out about the perfect temperature and time. Drinking tea can also have its tricky aspects, the importance of an indicator of

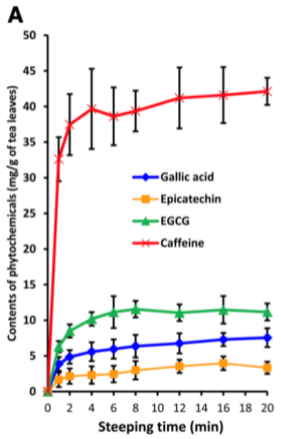


Figure 1: Kinetics of caffeine, gallic acid, and catechin extraction from CTC tea leaves. Reprinted from Fernando & Soysa (2015, p. 3), Creative Commons Attribution.

the right heat to enjoy tea is represented by the Internet phenomenon of sarcastic descriptions of how to make tea (see Figure 2). Unfortunately, drinking delicious tea with a burned

How to drink hot tea
1. Make cup of tea
2. Sip tea
3. Tea is too hot
4. Let tea cool
5. Forget you have a cup of tea

tongue is not very pleasant.

Figure 2: Popular tea process description on the internet.

The problem of tea lovers having to remember or to research the details of specific types of tea, over- or under-steeping, and concerns about the right temperature is solved by the ITea project. The device offers a practical solution to these problems by providing a convenient way to store and access tea-related information. Using NFC cards, users can easily enter the tea details once and transfer them to the device. In order to achieve the desired tea quality, there is no need for extensive research or reliance on external tools, like a manual thermometer or alarm clock. The ITea device aims to simplify the tea-making experience by combining essential functions in one device. It incorporates features such as a display, a timer and a temperature calculator.

With the ability to keep track of the set time, there is no longer a need to constantly keep an eye on the tea or manually use

a separate timer. The ITea device takes care of this task. Users can relax and do other things while the tea is brewing. In addition to the timer function, the ITea device also allows the user to keep track of the brewing status of the tea. They can follow the progress of the tea on the display or the website, from the time it takes to brew until it reaches the optimum drinking temperature. This visual feedback provides reassurance and helps to ensure that the tea is brewed exactly as the user wants. Users can also receive push notifications to their mobile phones. With this, they are always aware of the state of the tea, even if they are not close to the Itea device. This allows the user to be flexible and use their time efficiently without worrying about the tea.

Furthermore, the ITea device reduces hygiene issues and the risk of cross-contamination. Unlike fully automated machines, it avoids direct contact with the tea, ensuring cleaner and safer tea preparation. With regard to the functions of the device, it allows the user to have greater control and precision when it comes to brewing tea in comparison to an automated machine.

In summary, the ITea device offers tea lovers a convenient way to brew their favorite tea. Users can keep track of the brewing time without having to constantly monitor it, thanks to the device's timer function. The brewing status of the tea can be easily monitored on the device's screen. This ensures precise and personalised tea preparation. In addition, the ITea sends push notifications to users' mobile phones. This keeps them informed of the tea's progress even when they are away from the device. By providing tea lovers with these features, the ITea project aims to enhance the tea-drinking experience. By simplifying the process, improving accuracy and promoting a more mindful and relaxed tea culture, it helps users overcome the challenges of achieving the perfect cup of tea.

2 Related Work

In the scientific paper "Smart Tea - Coffee maker" (Singh et al., 2019), the authors present their idea of developing a device that "can make our cup without us being near the dispenser" (p. 79). This led them to develop a fully automatic tea and coffee maker that makes tea or coffee at the touch of a button. The team's idea was to further expand this system to allow for the interaction to happen via an app on the smartphone or to have it fully integrated into the so called “smart home”. Their proposed machine uses an Arduino Uno Main board to control the whole machine, and an W1209 Temperature control unit to determine the temperature of the water to turn on/off other components. A DC motor controller is used to determine the position of the cup with the help of an IR based Proximity sensor. The cold water and hot beverage are pumped via two solenoid valves. The general idea of making the tea brewing process easier and faster is something we got inspired by. In contrast to the device by Singh et al. (2019), the ITea device still needs a human interacting with the machine and won’t be fully automatic. Our device addresses the hygiene issue, which Singh et al. (2019) described as being “the biggest conundrum” (p. 79).

In the paper “The Espresso tea maker with IoT”, Gomathy et al. (2021) describe the operation of an espresso tea machine. The machine has three boilers for boiling the tea powder, the milk and the mixture. The boilers are connected to an air pump that facilitates the transfer of components from one boiler to another. The machine has a touch screen interface that allows the user to prepare tea, adjust the temperature and clean the machine. It is connected to the internet via Wi-Fi and works by inserting a coin. The machine's electronic board is controlled by an Arduino Mega microcontroller, and a Raspberry Pi module is installed for data transfer between the upgraded machine and the Ubidots cloud server via the internet. The Node-RED processing on the Raspberry Pi is defined as an IoT device using the Message Queuing Telemetry Transport (MQTT) protocol.

The authors of this paper highlight the purpose of this project as a help to make daily routine bright by being able to “prepare a cup of tea in one go by tapping on a single button” (Gomathy et al., 2021, p.1) his project was relevant to ITea especially due to the similar system architecture and the use of micro controllers and sensors. Also, the project deviates from ITea as it doesn’t provide temperature and time preference for brewing.

In the article “The Messaging Kettle: It’s IoTea time”, Soro et al., (2015) discuss the importance of considering people in the design of the Internet of Things (IoT) and present a prototype of a messaging kettle as a human-centered approach to the IoT. The Messaging Kettle is a system designed to enable remote communication between two people using a shared kettle. The system consists of two devices that complement a common kettle to provide temperature sensing and voice/scribble messaging capabilities. The Kettle Mate is shaped like a kettle and contains an Arduino microcontroller, an infrared temperature sensor, a microphone, and a speaker. It provides voice messaging controlled by a minimalist user interface for recording and playing messages. The smart tea box is an Android tablet embedded in a hardwood tea chest, with doodling and message archiving capabilities. The two devices communicate via Bluetooth and an embedded GSM chip is used for internet connectivity. The Messaging Kettle restores the intimacy associated with the ritual of boiling the kettle to make tea and provides a 'red phone' connection between two locations.

The Kettle Mate recognizes the local kettle's state of use, such as being switched on, boiling or cooling, and provides a visualization of the remote kettle's state of use through an orange/red glowing animation. The smart tea box allows the user to draw small notes with a pen and scroll through previous messages. It also allows the user to change the ink color, erase mistakes, post a message, and browse received messages. The Messaging Kettle is linked to an identical companion device, possibly several time zones away, to enable remote communication. The system does not interfere with the original and primary use of the kettle and allows people to use their own kettle.

The purpose of this project is relevant to ITea as it’s about tea making with a user centered approach without fully being automatic. What made more interesting about this project is their system architecture that is based on IoT.

3 Use Cases

3.1 Multiple users in an office brewing tea and saving instructions on NFC chips

In an office setting, multiple users, including employees and visitors, have access to a tea brewing station with the ITea device. Attached at every available tea box is an NFC card containing its brewing instructions. When a user arrives at the tea brewing station, they select their desired tea and place the box next to the ITea device. If someone brings a new type of tea to the office they can use one of the NFC cards to save the tea brewing instruction. To do this, they start the ITea device and scan the QR code leading to the ITea Telegram Bot. In a natural language conversation with the bot the user can store all information (name, amount of tea leaves, infusions, temperature, steeping time) on the card attached to a tea box. After this, the newly written card attached to the related tea box can be used to start the tea brewing process assisted by the ITea device.

3.2 Brewing tea with no experience and getting Telegram messages

Lea, a 18 year old high school student has never brewed any kind of tea before. Her mother however owns an ITea device. The instructions are displayed on the OLED screen on the device. First, she takes the favorite green tea her mother always makes and places it on the NFC reader. Now, she can select if she wants to brew the first or the second infusion. She selects the first infusion. The screen now provides the instruction to boil water, pour it in a cup and put the cup on the ITea device. When the weight gets put on the scale, it automatically starts a timer. This timer is for the time she has to wait until the water has the needed temperature. Her mother explains her that green tea should never be brewed with boiling water, but always with a lower temperature. While the timer is running, Lea and her mother go in the basement to do laundry. Before they go, Lea scans the QR code leading to the ITea Telegram Bot and texts “/start”. While they are downstairs, Lea gets a Telegram message that the water now has the desired temperature and she should put the tea in the water. She goes upstairs, puts the tea leaves in the water, and presses “enter”. A second timer starts. This timer is shorter and Lea waits next to the device until it is over. A timer sound and a blinking lamp gets her attention when the time is over. Lea gets her tea and sits down to read some magazines. Time flies by and she forgets about the tea. Luckily the device makes a sound again and she gets a Telegram message reminding her to drink her tea.

3.3 Additional information on the website

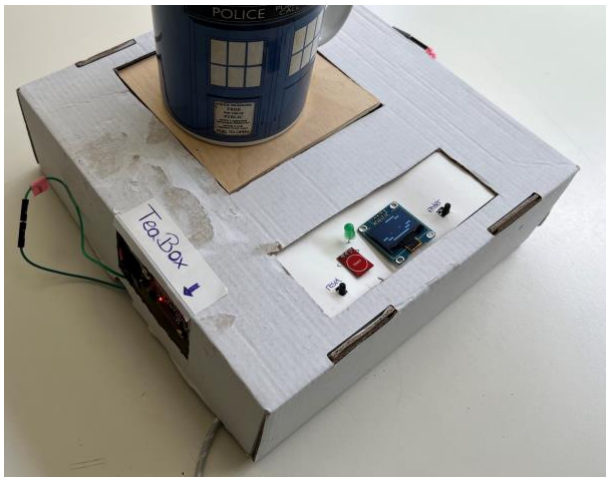
Max, a student at the Saarland University, wants his tea to be perfect. He knowns a lot about the different variables, which influence the flavor of the tea and wants to adjust his tea brewing to these variables. Normally, he uses a tea thermometer and a timer. But he heard that the ITea device can replace these tools and provides all the information he desires. Max brews tea with the assistance of the device. While he is waiting for the water to cool down he scans the QR code leading to the Telegram Bot. In the introduction message of the bot he finds a link to the website connected to his specific device. He opens the link. On the website he finds a dashboard presenting detailed information about the running timer, the last instructions, and the approximated current water temperature. He compares the temperature on the website with the information on his own tea thermometer. He is satisfied with the approximation. It is not excat, but close enough. After the tea is ready and he tries it, he decides to adjust the temperature information and to brew the next version of this tea with lower temperature. To do this he uses the Telegram Bot to write the new information on the card attached to the tea box.

4 Implementation

4.1 Design

The ITea is designed as a compact box measuring approximately 25 x 25 x 15 cm. The cabling is hidden inside the closed box. This ensures that the user does not accidentally come into contact with it. There is a special cut-out for the scale platform at the top of the unit. This is where the user can place the cup to start the process. The control panel is also integrated into the top. The control panel consists of an OLED display. It provides the user with information about the tea preparation status. In addition, there are three buttons on the control panel that allow the user to select from a variety of settings and options. To inform the user of progress or certain conditions, an LED display is also integrated into the control panel. On the left-hand side of the box, there is another cut-out that is specifically designed for the NFC reader. This allows users to place the tea box with the NFC card on the side of the device for quick and easy reading.

Figure 3: Design of the ITea device.



4.2 Hardware

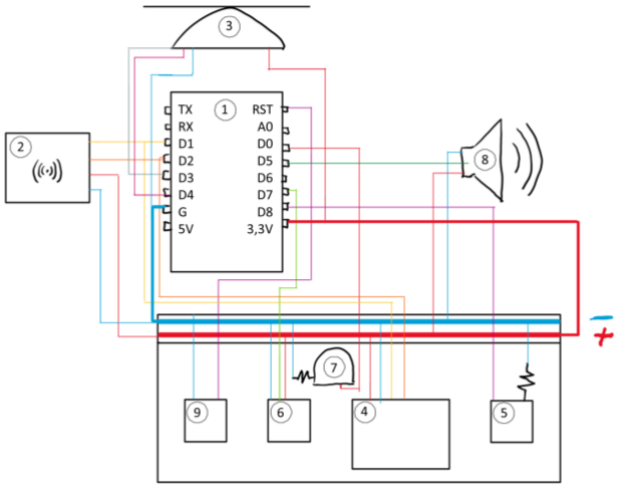


Figure 4: Wiring diagram of the ITea device.

The hardware used in the ITea project and its purpose:

1. The Wemos D1 Mini microcontroller (ESP8266) is the main controlling unit for our project. It manages everything, from the information given by the sensors, to calculating the time it takes for the tea to cool down.
2. The NFC RFID card reader (PN532) is a reader and writer of information on NFC cards to determine the difference between two types of tea.
3. The Scale Module (HX711) with load cell is used in order to determine if the user put the cup of tea on the device to start the timer based on the previously entered information.
4. The OLED display (SSD1306, 128x64) is used to show instructions.
5. An Enter tasters is used to confirm the selection and continue brewing.
6. A touch button (TTP223) is used to switch between two options, one or two infusions.
7. A green LED is used to signal to the user that the ITea device is ready to receive a new input from the user.
8. The Buzzer sounds an alarm when tea cools down sufficiently for drinking.
9. A Reset taster is used to resets the device in case of a crash and/or to restart the process for a new brew.

In addition, the project also requires a power source, wires, resistors, breadboards.

4.3 Usage

The entire process and use of the device is shown in Figure 6. At the beginning, the user is greeted with a welcoming message (Step 1). The NFC card has to be written with information about the specific tea that should be brewed (Step 8) before using the ITea device. This is possible with the Telegram Bot, accessible via QR code on the device. Additionally, the Telegram Bot can send notifications on the mobile phone (Step 9). The ITea device is ready to use once the information is stored on an NFC card. The NFC reader in the device automatically reads the information from the card (Step 2). The information is displayed on the device screen and on the website (Step 3). The user then selects an infusion and places a cup with boiling water on top of the device. The scale detects the weight of the cup (step 4) and starts the cooling timer to reach the required temperature for the brewing of the specific tea (Step 5). After this initial timer has been completed, the user should add the tea and press the Enter button to start the brewing timer (Step 6).

The device beeps when the tea is ready to be removed from the cup. A drinking temperature calculator is built into the device. It runs in the background and notifies the user when the perfect drinking temperature is reached and user is reminded to take action by a flashing green LED (Step 7). The connected website is accessible through a provided link from the Telegram Bot. There, the user is able to follow the instructions, the current timer and the temperature of the water (Step 10).

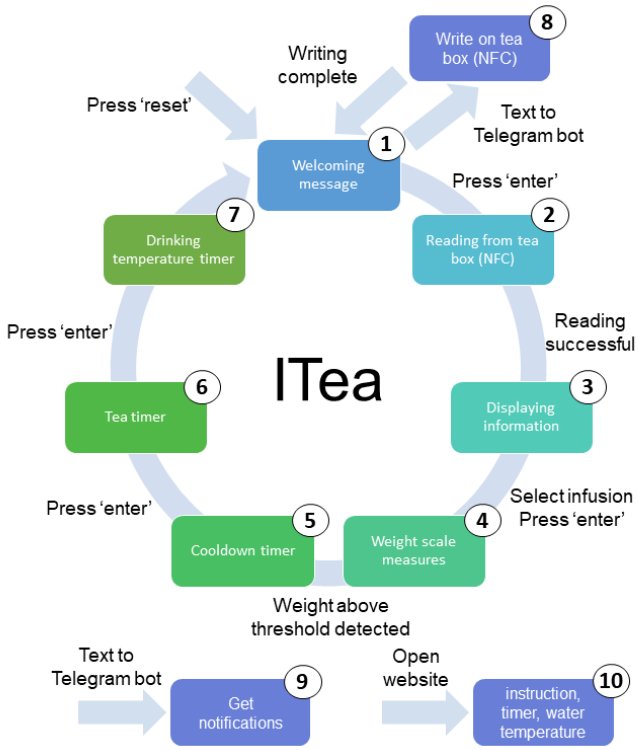


Figure 5: Process diagram of all functions of the ITea device.

4.4 Technical Considerations

One of the biggest challenges was integrating the PN532 NFC reader. The first problem we encountered was about accessing the text information saved on an NFC card with the NFC reader and save it as a String variable. Most libraries access the message on the NFC reader page wise, which makes it hard to save the whole text. We successfully combined two libraries: NDEF (Don, 2018) and PN532 (Seeed-Studio, 2022). Code snippet 1 shows the part of the code which saves the complete message on the NFC card as a string.

```
String payloadAsString = ""; // Processes the message as a string vs as a HEX value
```

```
for (int c = 0; c < payloadLength; c++) {
  payloadAsString += (char)payload[c];
}
Serial.print("  Information (as String): ");
Serial.println(payloadAsString);
print = payloadAsString;
```

Code Snippet 1: Read message from NFC card with NDEF and PN532 libraries.

The second problem is about the unreliability of the NFC reader. The NFC reader seems to be very sensitive and often fails connecting, especially after used in a row. This problem seems to be very common as it is discussed on many forum entries (e.g., user53213, 2019). For our prototype we found a sufficient but not fully satisfying solution. We found out that the NFC reader works better after restarting it, without reseting the whole device. Therefore we placed the power wire of the NFC reader in a way it can easily be accessed, disconnected and connected again.

Figure 6: Power cable of the NFC reader.

The third problem with the NFC reader is that is sometimes reading parts of the text message on a card in a garbled way turning the letters into unreadable characters (e.g., ?@%;?). The only successful way to reduce this problem was to make the message on the NFC reader as short as possible and to add an error handlin in the code. Code snippet 2 shows the beginning of the code which saves the information on the card in separate variables (name, infusion, spoons, gram, temperature for both infusions, minutes, and seconds for both infusions). The variables are only saved if the message doesn't include special characters. Else the user should repeat reading the NFC card.

```
if ((payloadAsString.indexOf('?') == -1) &
(payloadAsString.indexOf('@') == -1) &
(payloadAsString.indexOf('}') == -1) &
(payloadAsString.indexOf('"') == -1) &
(payloadAsString.indexOf('+') == -1) &
(payloadAsString.indexOf('!') == -1))
    {
     int Input1 = payloadAsString.indexOf("en");    // searching
for first Input (after "en")
     int end1 = payloadAsString.indexOf(';', Input1); // searching
for end of name Input
     name = payloadAsString.substring(Input1 + 2, end1);
```

Code Snippet 2: Beginning of an if statements which only saves the message on the NFC reader, if it doesn't include special characters.

Our initial plan was to attach a temperature sensor underneath the place the cup should be put. After we connected the temperature sensor we tested how good it could detec that a cup with hot water was placed on the device. We noticed that the reaction time of the sensor was too slow to start the timer with a hot cup. Therefore we decided to replace the temperature sensor with a weight scale. In the current prototype the weight of the cup triggers the timer. The downside is that we cannot detect anymore if boiling water is put into the cup. We solved this by instructing the user to first boil water, then put it in the cup and last place the cup on the device.

After these decisions, there are still some technical limitations to consider. For one thing, the NFC cards cannot be attached to any metal tea boxes, because the metal interfers with reading the card. Inconventiently, metal is the most commen material for tea boxes. Therefore, if the device enters the market it should provide its own tea boxes made of a different material.

4.5 Firmware

The function in Code Snippet 3 is used for the calculation of the time required for the cooling of water to a certain temperature. Newton's Law of Cooling is used for this purpose. The desired temperature (reqtemp) is given as input to the function. It then calculates the time (result) that is required to cool the water from the initial temperature (which is assumed to be 100.00 °C) to the desired temperature. The natural logarithm is used to calculate the ratio of the temperature difference to the initial temperature difference. This ratio is divided by the cooling coefficient (k = h·A/C = 0.00047632) to obtain the time. This is derived from the heat transfer coefficient (h = 99.55 W/(m2·K), the area of heat exchange (A = 8 cm), and the heat capacity, c = 4182 J/kg°C.

Code Snippet 3: Calculating time for cooling down water.

```
result = (-log((reqtemp - 22.00) / (100.00 - 22.00))) / 0.00047632;
```

5 Pseudo-Evaluation and Results

Using the ITea device, users should be able to brew tea adhering to the exact tea brewing instruction. Due to the device assisting with the complicated instructions, the tea brewing process should become easier and more relaxing. Therefore, we test in a pseudo-evaluation (1.) if the temperature approximation is close enough to the real temperature and (2.) if the device is easy to use and relieves the user.

5.1 Temperature Approximation

To approximate the time the boiling water needs to cool down to the correct temperature, the ITea device uses a formula based on Newton's law of cooling. This formula contains multiple

variables the ITea device cannot measure like ambient temperature and the diameter of the cup. For these variables we used average values: an ambient temperature of 22°C and a diameter of 8 cm. In the pseudo evaluation we test to which extent these approximations lead to deviations of the temperature after the calculated cool down period from the desired temperature.

5.1.1 Study Design. We used a tea thermometer to assess the water temperature (more) objectively, a room thermometer to assess the room temperature, and a tape measure to assess the exact diameters of the cups. We used the device repeatedly while systematically manipulating the following variables: goal temperature, room temperature, and cup diameter. After every round we assessed the exact water temperature with the tea thermometer and calculated the difference to the desired temperature.

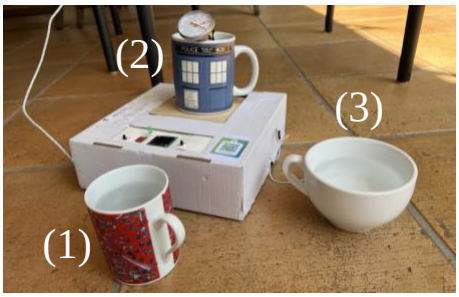


Figure 7: Measuring the exact temperature outside at 31°C. (1) diameter: 7 cm (thin walled); (2) diameter: 8 cm (thick walled); (3) diameter: 10 cm (thick walled).

5.1.2 Results. Figure 8 shows the different combinations of variables for two desired temperatures, the calculated waiting time, and the assessed temperature after the waiting time. The range of the measured temperature was 71-80 for a goal temperature of 80°C and 54-65 for a goal temperature of 60°C.

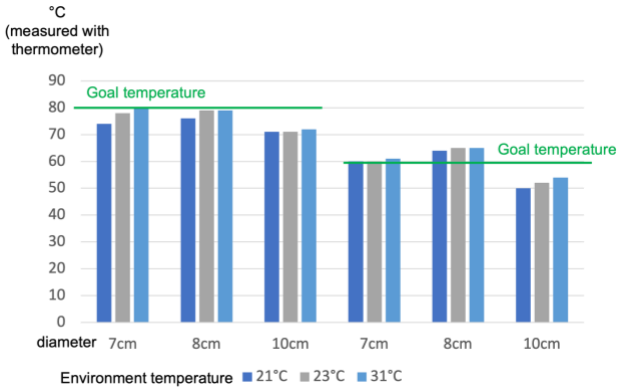


Figure 8: Water temperature measured with a tea thermometer after the calculated waiting time

5.1.3 Conclusion. Figure 8 shows that the measured water temperature was relatively close to the goal temperature, especially for a common medium cup. Interestingly, we found that the environment didn't influence the temperature as much as the type of cup did. For the finale device, we propose to keep the approximation of the environmental temperature, because it will be mostly used in room temperature and if not it doesn't change the water temperature too much. Instead, we suggest to capture user input about the approximate shape and material of the cup they are using. The final device should have a menu in which the user can select a cup size out of multiple drawings and select the thickness/material of the used cup.

There are several limitations with this part of the evaluation. First, the thermometer was possibly not completely accurate and needed some time when put in the next cup to measure. Second, the environments differe in more than in the temperature. The measurement outside (used for higher temperature) offered more air exchange then the one in the basemenet (used for lower temperature). Also, the cups differed in more than the diameter, especially the 7cm cup was thin walled, while the other ones were thick walled (to be seen in figure 7).

5.2 User Testing

The primary goal of the ITea device is to lift the load from the users. We conduct a user testing with three participants to evaluate whether the device reaches this goal.

5.2.1 Study Design. We recruited two participants who regularly brew tea with varying required temperatures and who haven't used the device before. The testing took place in a quiet environment. We provided the participant with a water boiler, a tea box with an attached NFC card, and the device. Using a script (attachment A) the moderator first asked the participants some discovery questions about the participant's tea drinking behavior and then led the participant through a think aloud protocol. This means the moderator asked the participant to use the device and while using it to speak their thought out aloud. The moderator stayed neutral and let the participant use the device on their own, only helping if the participant is not able to continue on their own. During the longer waiting periods (while the water cools down) the think aloud protocol was paused, and the participant could use the time to go through demographic questions. The moderator took notes on the participant's behavior during the think aloud period. With the consent of the participant the audio during the think aloud period was being recorded.

After the think aloud period, the participant filled out the System Usability Scale (SUS) (Brooke, 2013). This is a very common scale used to measure the general usability of system since 1986. To get the score, the answers on a scale (0-4) are add up and multiplied by 2.5. This way the score is on a scale from 0 to 100.

Afterwards, the moderator conducted a short debriefing interview. During this, they reviewed parts of the test where the user struggled. The moderator additionally asked about the user's preferences ("What did you like/dislike? Which parts are most/least important for you?"), possible changes ("If you had three wishes to make this better for you, what would they be? Why?"), and use cases ("Under what circumstances would you use this? Why?"). One user test took around 30 minutes.

5.2.2 Results. We conducted a user testing with two users. User 1 is a 22 years old who drinks tea regularly but not daily. They

know about teas which need different temperatures and infusions times, but don't drink these types regularly. User 2 is a 58 years old daily tea drinker who dialy drinks green or black tea and who is concerned about the correct temperature and time. Both users have high technical literacy.

During the process of writing on the tea card via the Telegram Bot, both users paused when asked to type in the time. They were not completely sure in which format to put in the minutes and seconds. Regardless of this pause of confusion, both users successfully completed writing on the tea card without help. Afterwards, user 1 independently continued with starting the tea brewing process. User 2 on the other hand, did not completely understand the instruction in the main menu ("Welcome to ITea; Write on tea card: text bot /write; Start: press enter"). She didn't understand that the writing process was already finished and texted the bot a second time. At this step the moderator interrupted and helped the user to get on the right track again.

During the tea brewing process, both users mastered the task on their own. They followed the instructions without long hesistation or confusion. After the user test was over, the moderator demonstrated more advanced features, which were not covered in the first usage (the website and getting notifications via Telegram).

Here are some quotes from the debriefing interview about what the participants liked while using the device:

- "I really liked the smooth transition of phases, you always knew when to wait, the numbered steps, what to do after you wait"
- "Maybe it is especially handy for people who are not good with apps because everything is in one physical device"
- "Often it can be beneficial not to be bound to a full automate: In the office or a big household everyone can come with their own cup and use the device. And tea automates calcify, not this device."
- "Better than kettles that boil to a certain temperature but don't tell how long the tea has to steep"

These are the thoughts of the participants about things they didn't like or things they would wish for a future version:

- "Adjust the formulations to make some of them more understandable"
- "I struggled with the input of minutes and seconds in Telegram"
- "After using Telegram to write on the card I wasn't sure whether to continue using Telegram to go through the steps or to push a button"
- "Writing on the card was the trickiest part (because complex), after that the device was very intuitive to use"
- "I wouldn't like to use Telegram as a tool. Perfect would be to have a big enough touch screen to input all information directly witht the device."
- "You should provide a preset list with tea types"
- "In the final version, the plate for the tea cup could be more stable and could have a cutout for the cup"
- "The device also should be more compact for the daily usage"

User 1 had a SUS score of 75, while user 2 scored with 82.5 (on a range from 0 to 100). Both values are in the range which is usually interpreted as good usability.

5.2.3 Conclusion. Especially user 1 had many thoughts about reformulating some instructions. Therefore, after the user testing we asked them for their opinion about how it should have been formulated to be better understandable. We adjusted multiple formulations in the Telegram bot and made the main menu in a way which makes it easier to understand the two options (writing on the card OR starting the tea brewing with the device). Apart from fromulations we didn't make further adjustments, due to time constraints.

These are the features that should be implemented in a finale version of the device to meet the users needs: A bigger screen with enough space to make the instructions and options on the main menu easier to understand; possibly a touch screen to type in the tea information instead of a Telegram Bot – alternatively, a self-hosted ITea App with an own chat bot to be independent from messanger apps; a preset list of tea types to choose from; a physically more stable and compact device made out of water proof material.

Regardless of these suggestions for improvement, we conclude that (after minimal adjustments of the instructions) both users were able to use the device on their own and both users saw a lot of benefits in using the device to assist their tea cooking process.

6 Conclusion

Tea brewing can be a complicated and overwhelming process, especially for novice users or users who share the same tea equipment (e.g., in the office or a hotel lobby). The ITea device represents a step towards a more intuitive and more informative tea brewing process. It eliminates the need for multiple kitchen helpers (thermometer and timer), while avoiding the downsides of fully automated tea brewing machines (calcification, hygiene). At the same time, it provides the user with all the information they'll need about the tea brewing instructions directly accessible with their tea box. And moreover, the users have easy access to more information then they ever had before, provided by a website dashboard with live information about the approximated water temperature, the current timer and the next instruction, and a chat bot, sending reminder messages after the waiting times end.

Our user testing showed that users recognize and value these benefits and that the device is easy and intutitive to use. A systematic test of the approximated waiting time for the water to cool down to the goal temperature showed that the used formula is close enough but still can be improved in a future version. The most promising variable to make the formula more exact is the shape of the used tea cup, which could be selected by the user.

While the usability of the device already improved in the process of user-centered design, there is still a way to go before all of the users' needs are met. The final version should integrate additional features like a bigger screen (probably touch), a self-hosted App, and a preset of tea types.

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