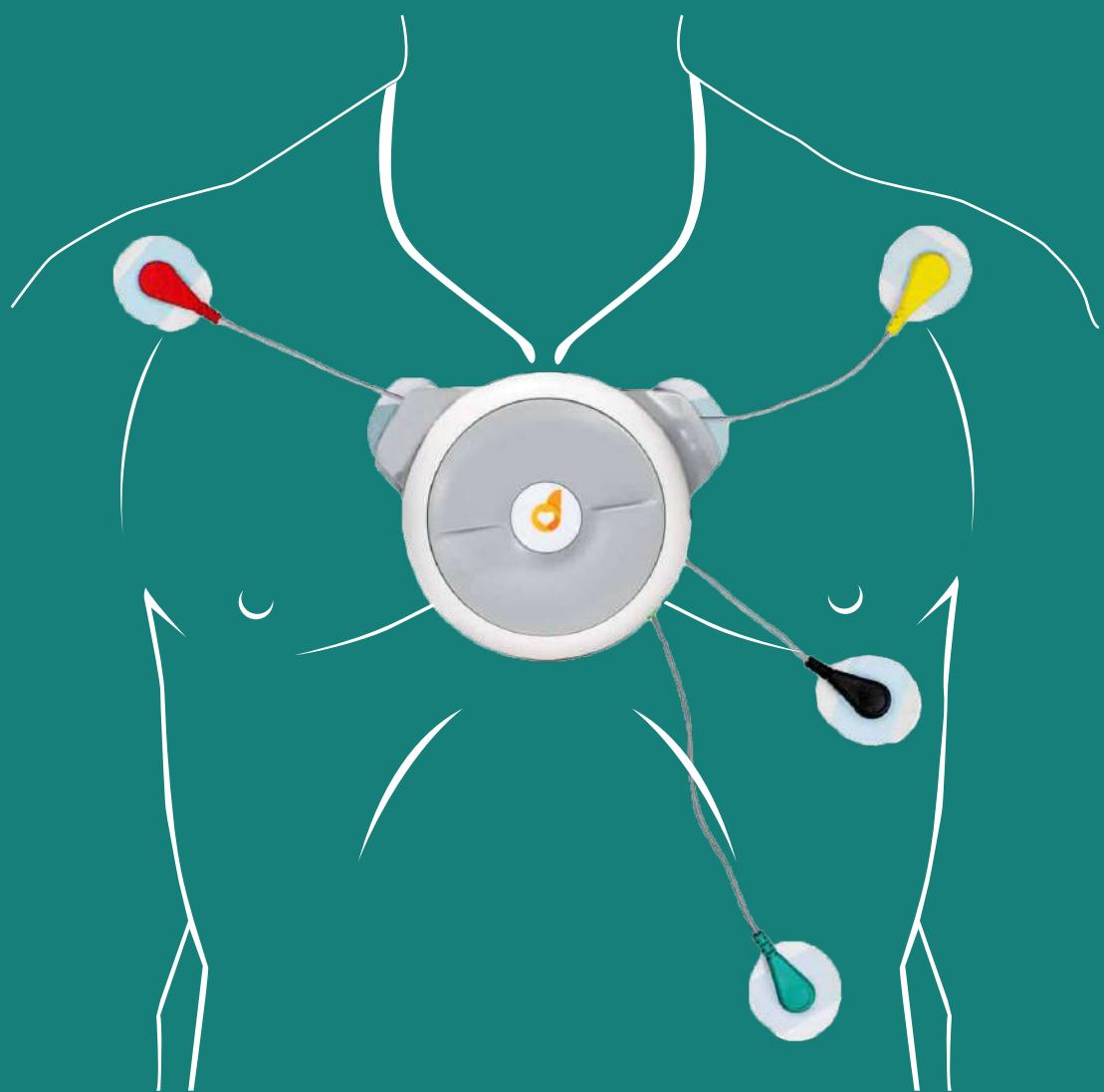


UX Research Report on D-heart

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1. EXECUTIVE SUMMARY

D-Heart is an accessible ECG (Electrocardiogram) system designed to enable users to perform ECG tests anywhere, without requiring any medical background. Consisting of a portable device and a mobile application, D-Heart is certified and is as clinically reliable as hospital-grade electrocardiographs. It offers enhanced ease of use compared to traditional medical equipment. Users can monitor their heart health by conducting ECG tests with D-Heart on their smartphone, and share the results with trusted cardiologist or telecardiology services for comprehensive reports.

Our research employed expert evaluation and user testing to identify usability and user experience issues with the D-Heart system. Targeting the needs of our primary users, as identified during our research, namely university students who prioritize health despite demanding schedules, we aimed to suggest redesign guidelines. These users often stay up late and sometimes experience tachycardia or arrhythmia. They are also affected by a family history of heart disease, yet lack medical knowledge, leading to concerns on their own heart health. Despite realizing the importance of prevention over treatment, they find it challenging to monitor and understand their heart health due to limited resources and time.

Through our research, we identified the user needs, including affordability, ease of use, reliability, convenience, simplicity, understanding, engagement, and communication. Despite limitations in representing the broader user population, our study provided insights to infer design requirements aimed at addressing these needs and enhancing the device and application.

From the data gathered, we inferred design requirements to enhance the device and application. These include affordability, ease of learning, reliability, efficiency, simplicity, clarity, smoothness, timely feedback, interpretation, and youth preference. Additionally, we proposed incorporating a sharing mode for the device, and interactive channels to bridge users and experts, facilitating further communication and understanding of heart conditions.

2. BACKGROUND OVERVIEW

Main problems

- Current ECG monitors with 8/12 leads, known for their enhanced diagnostic capabilities, are typically bulky and designed for hospital use.
- The high cost of these monitors is mainly attributed to the intensive CPU requirements for data processing within the machine.
- These machines cater to experts who know how to conduct ECG test and read the data, posing accessibility challenges for non-specialists.
- The complex appearance of medical products for ECG monitors can intimidate ordinary users, hindering user engagement.

These issues were identified by D-heart developers, prior to conducting this research through our expert evaluation and user testing, as we will further elaborate in the fourth part of this report, titled "Key Findings."

Research Goal

This report aims to emphasize identified usability and user experience issues, and provide design requirements to better meet the user's needs as identified during our research, enhancing the D-heart system to drive its ongoing improvements to ensure D-heart is a top-tier home cardiac monitoring device.

Initial State of the Product

- The initial state of the D-heart device is portable and packaged within a box designed with holes for storing the ropes, charger cables, and the phone. It also includes two user manuals.
- The application is designed to receive and process the detected data, which reduces the demand on the CPU inside the device and thus lowers its cost.
- To prevent non-specialist users from mis-positioning the electrodes, the application utilizes the phone camera and electrodes of different colors.
- The device has a simple and non-intimidating appearance.

Background Information

The patents and certificates for this medical product have been secured by the development team. For detailed information, please refer to the links provided in Appendix A

3. METHODOLOGY

Expert Reviews including Heuristic Evaluation and Cognitive Walkthrough were conducted to identify usability problems and strengths of D-heart. User testing was carried out to see if the functions of D-heart correspond to users' expectations and how well they serve their wants and needs, and also discover hidden issues.

3.1 Heuristic Evaluation

Each of our 4 group members acted independently as an expert in the heuristic evaluation of D-heart, since we tried to have a preliminary understanding of this product, and figure out the tasks that real users may need to complete. Most of us have experience of UX design and knowledge of usability principles, in addition, we were not involved in creating the design to be reviewed.

We determined to evaluate with a set of heuristics: Jakob Nielsen's 10 Usability Heuristics, and developed a use scenario: A female patient who is around 50 years old and has heart diseases, she uses D-heart to monitor the effectiveness of medications. The user's goals and expectations are:

1. Easily use the product to monitor her body every week;
2. Medication Adjustment: The primary goal may be to adjust and fine-tune medication dosages or types to achieve optimal control of the heart condition.

We identified the main tasks users would probably need to perform:

1. Set up the app
2. Set the device
3. Connect the device via Bluetooth
4. Place the phone and know the electrode placement(use the camera)
5. Place the D-heart & electrodes, and record the ECG results
6. upload the report & Get the answer from the doctors within 15 minutes

While performing the analysis, we took notes, photos and screenshots and annotated them. After each of us conducted the evaluation, we gathered independent observations, discussed to synthesize the issues and assessed severity rating in a document (Full details are given in Appendix B).

3.2 Cognitive Walkthrough

We reused the main tasks in the heuristic evaluation and analyzed the steps to complete each task. One group member acted as a facilitator. All members served as evaluators, offering their interpretation of how a new user would perceive the interface and behave in the given situation. Another member served as the recorder, documenting the answers found for each question and the probable success or failure of the overarching task. After all steps have been evaluated, we summarized the fail points. The reason why we used this methodology is that we want to evaluate the learnability of D-heart from the perspective of a new user. (Full details are given in Appendix C).

3.3 User Testing

Although we designers act as experts and can identify some design problems of this product, user testing may uncover issues that an expert may have not thought of, because the real audience has very specific knowledge or needs. We have to get hold of real users and see what they do to get a true assessment of whether this design is easy to use, solve people's needs. User testing is also really cheap, we are just students and are tight squeezed in the budget, and we also have a short time schedule, user testing can be done in just few days.

Following is how we conducted our user testing:

1. Recruited 12 participants according to the 2 scenarios determined in the task analysis;
2. Asked participants to sign the consent form (please see Appendix D) for user research activities;
3. Implemented a pre-test interview to get participants' heart condition and experience of health devices;
4. Gave participants representative tasks to perform, while continuously thinking out loud;
5. Observed and noted down their behavior, videotaped them, recorded the time they consumed on each subtask;
6. Assessed their emotion and difficulty level of subtasks after they finished each subtask;
7. Asked participants to fill in SUS or UEQ questionnaire after they finished all the subtasks.
8. Undertook a short interview with participants

3.3.1 Task Analysis

D-heart is used to monitor heart health and explain possible unclear symptoms or monitor the effectiveness of medications, so users of D-heart are various. We considered that there are some users perform the ECG testing for the older families, and some users do the testing by themselves. We determined 2 scenarios and the tasks users would take as follows:

Scenario 01:

A young adult whose parent is around 60 years old and has heart diseases, she uses D-heart to monitor parent's effectiveness of medications.

Task:

Perform the ECG test for the parent at home

Subtasks:

1. Set up the app
2. Create a patient profile for the parent
3. Connect the device via Bluetooth
4. Set the device on the parent following the guidance
5. Perform the testing following the guidance
6. Send the report
7. Take off the devices for parents

Scenario 02:

A young adult who always goes to gym for exercise, and may occasionally feels heart or chest pain, he uses D-heart to explain possible unclear symptoms.

Task:

Execute the ECG test alone at the gym

Subtasks:

1. Set up the app
2. Connect the device via Bluetooth
3. Set the device following the guidance
4. Perform the testing following the guidance
5. Send the report

3.3.2 Participants

We recruited 1 experienced users and 11 novice users to participate user testing, with 6 assigned to Scenario 1 and another 6 to Scenario 2. (Please see the details in *Table 1*) Each user took corresponding tasks, and each session took around 30 minutes, and the screen and voices were recorded.

One moderator was responsible for moderating the user testing session, one facilitator recorded the completion time of each subtask, and the other facilitators observed and took notes.

Participants	Age	Gender	Occupation	Nationality	Phone	Scenario	User Type	Heart Condition	Fitness Habits
User 1	20	Female	Student	European	iOS	1	Novice	Not at all	Not at all
User 2	24	Male	Student	European	iOS	1	Novice	Had Wolff-Parkinson when young	Regular gym-goer
User 3	24	Female	Student	Chinese	iOS	1	Novice	Not at all	Not at all
User 4	28	Female	Student	Chinese	iOS	1	Novice	Not at all	Not at all
User 5	24	Female	Student	Chinese	iOS	1	Novice	Not at all	Not at all
User 6	25	Female	Student	Chinese	Android	1	Novice	Not at all	Not at all
User 7	23	Male	Student	European	Android	2	Novice	Not at all	Regular gym-goer
User 8	23	Male	Student	European	iOS	2	Novice	Not at all	Not at all
User 9	24	Female	Athlete	European	Android	2	Novice	PFO	Regular gym-goer
User 10	23	Male	Student	Chinese	iOS	2	Experienced	sinus arrhythmia	Frequent gym-goer
User 11	28	Female	Student	Chinese	iOS	2	Novice	Not at all	Frequent gym-goer
User 12	24	Male	Student	European	Android	2	Novice	Not at all	Frequent gym-goer

Table 1

3.3.3 Observational Research

The observations took place while doing the user testing, we noted down how users behaved in each subtasks and what they said during the testing. Because it's essential to uncover user pain points in real context.

3.3.4 Premo

After users finished each subtask, we asked them to evaluate their own emotion of this subtask by choosing a Premo card, and we also asked why they chose that card. By doing this, we hope that we could encourage users to talk about their thoughts about the subtask they just did, and collect their contextual emotions, which is beneficial to analyze the issues of the product.

3.3.5 SEQ

After each subtask, we asked the simple question: *Overall, how difficult or easy was the task to complete?* Results were rated on a 7-step Likert scale from one (very difficult) to seven (very easy).

SEQ is essential to evaluate the task level satisfaction, which can help us orient the subtask with most issues.

3.3.6 SUS

System Usability Scale (SUS) consists of 10 questions focused on assessing the overall usability of a system, including ease of use, fulfillment of user needs, system complexity, user confidence and frequency of use.

SUS was chosen for our Scenario 1(*Perform the ECG test for the parent at home*), because it can focus efficiently on usability assessment and it suitable for scenarios in which rapid user feedback and product iteration are required.

3.3.7 UEQ

User Experience Questionnaire(UEQ) is made up of 26 questions which aims to evaluate completely the user experience of a product in multiple aspects, including Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty.

In our use testing, we chose the UEQ for Scenario 2 (*Execute the ECG test alone at the gym*), because it provides an in-depth assessment and comprehensive feedback on how user feels about a new feature or the product as a whole, making it suitable for designers who want to gain a deeper understanding of the user experience.

4. KEY FINDINGS

4.1 Usability

Usability of the device was measured after the user completed all the tasks in **scenario 1**, using System Usability Scale (SUS). The following table demonstrates the result of SUS.

User	User 1	User 2	User 3	User 4	User 5	User 6	Overall Score	Grade	Rank
Score	75	55	57.5	27.5	22.5	67.5		D	Poor
Grade	B	D	D	E	E	C			
Rank	Good	Poor	Poor	Awful	Awful	Okay			

Table 2

The data presented is based on testing conducted with a limited sample population consisting solely of student users. As such, the findings and conclusions drawn from this data may not be fully representative of the broader user population.

Based on the responses from 6 participants, the overall SUS score for the D-heart system was 51. According to the general guidance on SUS scoring interpretation (Peres et al., 2013), this result is considered as grade D, ranked “Poor”, and only one score is above 68(meaning Good), most scores are placed at “Poor” and “Awful”. This implies that **the product is not able to fulfill the most participants' needs. Most participants had a feeling of discomfort and thus, a negative attitude towards the application.**

4.2 User Experience

User experience level was measured after the user completed all the tasks in **scenario 2**, using User Experience Questionnaire (UEQ), which contains 26 questions on a 7-point scale with random orders.



Figure 1

Overall, the scores of perspicuity, stimulation and novelty are the lowest:

Perspicuity: It is not easy for users to get familiar with the product and to learn how to use it, and users may struggle to understand the system's interface and find it unclear.

Stimulation: Users find the system uninspiring and lacking in engaging elements. The product fails to capture users' attention, resulting in users becoming easily distracted or disengaged while using it.

Novelty: Users perceive the system as lacking innovative or novel features, failing to maintain their interest over time.

4.3 Effectiveness and Efficacy

Effectiveness was measured by the task completion rate. If the participant successfully completes the task in one attempt, will be marked as "E" (Easy) with one point. If the participant successfully completes the task in two attempts, will be marked as "H" (Hard) with half the point, if not, will be marked as "F" (Failed) with zero point. To achieve perceived effectiveness (PE), we will use the following Eq(1). Please see the detailed effectiveness result in Appendix E.

$$PE(\%) = \frac{"E" + ("H")}{Total\ Num\ of\ Tasks\ Taken} \times 100\% \quad (1)$$

Efficacy was measured by the task completion time. We calculated the average of the recorded time taken from 6 participants for each subtask. (*Participants who failed to complete a subtask were not considered in the calculation.*) Please see the detailed efficacy result in Appendix F.

Figure 2 (Data on the X axis refer to the subtask, for example, 1-1 refers to Scenario 1 - subtask 1), comparing effectiveness and efficacy of each subtask results, which indicates that 1-4 has most problems, and there also remain some issues in 1-1, 2-1 and 2-3.

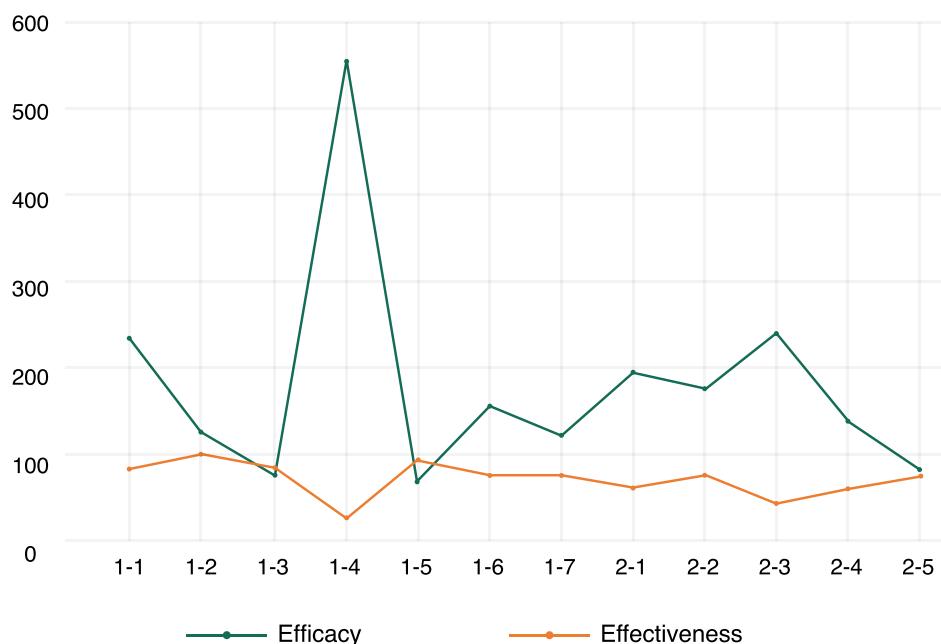


Figure 2

From what we've observed during the user testing and what we've found in expert evaluation, we summarize the following insights:

- **Error pattern 1:** Users frequently **encountered errors when attempting to set the device on the parent or on themselves**, (e.g. ①attach only 4 electrodes, ② not wear the lanyard, ③attach electrodes to the wrong position) this insight indicates potential issues with user guidance that need to be addressed to reduce frustration and improve task completion rates. (In 1-4, 2-3)

- **Error pattern 2:** Users usually failed to set the correct password for their account, only succeeding after multiple attempts, this insight indicates unclear password requirements, and overly restrictive rules hindering user progress.(In 1-1, 2-1)
- **Tutorial effectiveness 1:** Users who watched the video tutorial demonstrate higher completion rates and efficacy levels compared to those who skip it. This insight emphasizes the importance of a well-designed tutorial process in familiarizing users with app features and functionality. (In 1-4, 2-3)
- **Tutorial effectiveness 2:** Users can't follow the video tutorial, (e.g. ①Struggle to memorize the tutorial due to its excessive length, ② Some choose to skip the tutorial video ③Unable to watch the tutorial video again) this also implies the issue of guiding users during the testing. (In 1-4, 2-3)
- **Inaccurate feedback:** Users got no feedback or wrong feedback after they did something wrong. (e.g. ①Not know whether they attached the electrodes at the right place. ②Can click "NEXT" to start the testing, even though they attach the electrode incorrectly.) This suggests potential usability issues related to feedback mechanisms. (In 1-4, 2-3)
- **Visibility issues:** Most users ignored some unclear functions. (e.g. ①Not know where to click to start testing, ②Not notice the "Turn camera" button when taking photos for parents, ③Most female users didn't notice the "Switch gender" button.) This (In 1-4, 2-3)

4.4 Satisfaction and Emotion

Satisfaction at the post-task level was measured using the Single Ease Question (SEQ). The results are summarized by using the mean value. Please see the detailed satisfaction result in Appendix G.

User's emotion towards each subtask was evaluated by Premo, please see the detailed Premo result in Appendix G. We counted the number of positive emotions of each subtask.

Figure 3 (Data on the X axis refer to the subtask, for example, 1-1 refers to Scenario 1 - subtask 1), comparing satisfaction and positive emotion of each subtask results, which implies users are not satisfied with 1-1, 1-4, 1-6, 2-1, 2-3 and 2-4.



Figure 3

By integrating the answers of the users when they were asked “why”, their behavior during the testing process and expert evaluation, we get the following summary:

- **Account creation friction:** Most users **complained a lot and expressed disaffection during the account creation process** due to excessive form fields and there are too much terms and conditions to be agreed. Although they thought this subtask was not so difficult, they expressed unpleasant emotions. This insight indicates the need for simplifying the account creation flow. (In 1-1, 2-1)
 - **Error recovery frustration:** Nearly half of users **expressed confusion when they encountered some errors but had trouble rectifying errors**, (e.g. They can't return to homepage when entering Reminder page). (In 2-3)
 - **Postponed feedback:** Some users were **confused with the E-mail which read: ECG has been refused**, without exact reasons. This suggests that users need immediate and detailed feedback if there is something wrong. (In 1-6)

4.5 Generalization of Insights

Problem 01: Encounter errors when wearing the device	Problem 02: Not be guided well by the tutorial	Problem 03: No feedback/ Wrong feedback/ Postponed feedback	Problem 04: Feel psychological burden
Wear only 4 electrodes	They struggle to memorize the tutorial due to its excessive length	Users didn't know whether they attached the electrodes at the right place.	Users worry about making mistakes that could harm their body.
Not wear the lanyard	Users are unable to watch the tutorial video again, if they finish watching it or just skip it.	Users can click "NEXT" to start the testing, even though they attach the electrode incorrectly.	Users are concerned that incorrect operations may damage the device.
Attach electrodes to the wrong position	Some users didn't watch the video tutorial, just read the manual brochure.	Users can still click the button "Next", even though the loading icons don't all turn into check icons.	Users are burdened with caution and fear.
Attach the electrodes to body without removing the protective film from the electrodes	Some users choose to skip the tutorial video	Users who didn't wear the device correctly, will receive the E-mail that reads: ECG has been refused. (Equipment does not give immediate feedback)	User Needs Need to engage with the app free from pressure.
User Needs	Users don't have the patience to read the whole thing.	User Needs	Problem 05: Hard to notice unclear functions
Clearly understand the process of wearing the device	Users get confused due to the different meanings between the illustrations and the text in the manual.	Know definitively whether their actions are right and the reason for the wrong.	Users don't know where to click to connect device via Bluetooth.
Wear the device correctly	User Needs	Get real-time feedback at every step of the test	Users don't know where to click to start testing, and try to click the logo at the middle top.
Wearing the device without psychological pressure (feeling stupid)	Understand the tutorial faster.		Users don't know where to click to turn on the D-heart device.
Problem 05: Stuck by account creation friction	Don't want to pay too much attention.	Problem 06: Struggle to understand obscure and professional contents	It's difficult for users to notice the "Turn camera" button.
Users set passwords several times un-smoothly.	Reduce the memory/learning curve	Some of the knowledge given in the report can only be read by professionals	It's difficult for users to notice the "Switch gender" button.
The keyboard overlaps the requirement of password.	Attention is engaged in segments rather than all at once	The content of some of the options that need to be filled in is confusing to the user.	Users didn't understand the status of the bluetooth connection when the user's mobile phone Bluetooth is initially on.
Users need to fill in a lot of boring information	Problem 06: Error recovery frustration	User Needs	Users don't insert their mobile phones into the specially reserved place on the product box
They had to log in again after registering.	Users can't return to homepage when entering Reminder page.	Wish to get some knowledge about the related science and technology.	User Needs
User Needs	Users didn't what to do when they failed to connect the device via Bluetooth.	Have an initial understanding of the results	Clearly understand the corresponding functions when using them
Create an account easily before testing	User Needs		No confusion or stagnation during use
Create an account in little time	More informative error messages to suggest possible solutions		
No need to create an account in an emergency			

4.6 Interview

Pre-Test Interview

[1] Have you felt discomfort about your heart? When?

User 3 & 5: Yes. When I **stay up late** and are busy with my studies.
User 4 & 6: Yes. Due to rapid heartbeats when I **consume too much coffee**.
User 11 : When I experience **anxiety and stress** during exams and feel palpitations.
User 9: I often feel discomfort because I have a heart disease (PFO).

Insight: Half of the users we interviewed have experienced heart discomfort, for both physical and psychological reasons.

[2] How will you test your health condition when feeling discomfort about your heart?

User 6: I'll skip testing because undergoing hospital tests involves **much time and expense**, especially if the discomfort doesn't significantly impact me.
User 3 & 4: I'll go for serious testing in hospital if I experience frequent discomfort.
User 11: I'll try to regulate my sleep schedule, and monitor my heart rate using my iPhone watch instead of hospital tests.

Insight: Hospital tests are unpopular among our users due to the considerable time and cost.

[3] Have you ever used ECG testing or other health testing product before?

User 1 to 10: I had ECG testing at the hospital during physical checkups.
User 9: I need regular checks because I have PFO.
User 11: I've used XiaoMi wristband / IPhone watch for ECG testing.
User : Never.

Insight: Most of our users are novice in terms of using ECG testing device themselves.

[4] Have you assisted others in conducting health tests using medical devices?

User 1 to 9: Never.
User 10: I've helped my grandmother who has heart issues to conduct tests at home.
User 4: I've helped my family member to test their blood glucose level with home blood glucose monitor.

Insight: Most of our users have no experience in terms of using medical devices for helping others conduct health test.

Post-Test Interview

[1] How do you feel about the process of using the device?

User 10: It's a bit **tedious and lengthy**. I don't have patience reading the long text in the manual.

User 12 & 10 & 2 & 3: A little **confused** like I don't understand the professional terms.

Insight: The user wants the product to be easy, clear and quick to use.

[2] What's your expectation about this product? Why?

User 10 & 12: I want to have a **basic understanding** of the tested data before the doctor's diagnosis.

User 12: I hope the result of testing from the D-heart as **reliable** as tested in the hospital.

User 6: I wish this professional equipment was more **readily available** for use.

Insight: The user wants explanation of specialized vocabulary to help him fill in the personal data on health condition; The user wants the product to be trustworthy and available for use.

[3] Would you like to buy this product?

User 10: It's **expensive** for me as a student.

User 12: No. Because i don't have heart problems for now, and it's expensive.

Insight: The user perceives the product as unaffordable.

[4] Would you like to use this product to do ECG test?

User 3 & 4 & 5: Yes. Because i often stay up late and sometimes experience palpitations, so i want to use it to check my heart status.

User 10: Yes. Because i'm concerned about my health, and my grandmother has heart issues, if it's useful I'd like to recommend it to my family members.

User 9: Sure, It's a great alternative, after all, go to the hospital is still troublesome.

Insight: The user is more concerned about his heart health when he has relevant family history; he also cares about his family's health and have willingness to recommend the device to others.

[5] Do you think you need support to use the device? Why?

User 5 & 6 & 11: No. Because I feel awkward when taking off my clothes to use it.

User 4: Yes. Because I'm still confused whether my operations will affect the outcome of the testing.

Insight: Most users tend to use the device alone.

4.7 Persona of Primary User

Based on expert evaluation and user testing, we have identified issues users encountered, user behavior, user feedback and user needs. Taking into account the aforementioned information, we have constructed our persona.



Lily

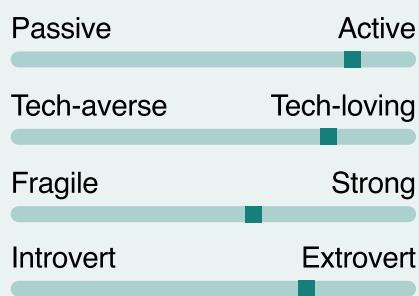
- **Ages:** 23
- **Occupation:** Student
- **Family:** Family members with a history of heart disease
- **Location:** Europe

“

I'm concerned about my health, and I do believe that prevention is better than cure.

”

Personality



Pain Points

- Too shy to ask for help
- No medical background
- Limited economic conditions

Bio

Lily is a university student, who is busy with her studies and always stays up late. She's concerned about her health due to her family history of heart problems, but she never tested the ECG by herself. Despite her limited time, she often goes to gym to take control of her well-being. She wants to monitor her heart health and adjust her fitness plan accordingly.

Needs & Expectations

- Access the ECG device affordably;
- As a novice, need learn to use and get familiar with ECG system easily and quickly;
- Need reliable and professional ECG device;
- Need to use the ECG system conveniently to save time;
- Expect a usage process that is simple and clear;
- Want to use the system without pressure;
- Get immediate feedback on whether her actions are correct, and the reason for errors;
- Want to understand more about her heart status and related knowledge;
- Need inspiring and engaging elements to capture attention and avoid boredom;
- Expect possible ways for further communication and understanding of their heart condition.

Motivation

- Concerned about her health
- Concerned about her family health
- Social sharing
- Promising result
- Willing to try new things
- Pursue fitness

5. DESIGN REQUIREMENT

5.1 Problem Statement

University students like Lily, who prioritize their health, often face situations such as staying up late and feeling unwell when experiencing a busy study life. Additionally, with a family history of heart disease but lacking professional medical knowledge, they feel concerned about their own heart health. Despite recognizing the importance of prevention over treatment, they find it challenging to track and understand their heart health due to limited financial resources and leisure time.

5.2 Vision Statement

We envision creating an accessible shared health monitoring system for university students like Lily, managed and provided by university fitness centers. This system will offer convenient self-service heart health monitoring services, allowing students to easily track and understand their health data among their busy academic schedules. Our goal is to reduce the time and financial costs of health management through this system, while also providing educational resources to help students understand heart monitoring and health-related knowledge and technologies without a medical background.

5.3 Design Requirements

- **Affordability:** provide a low-cost sharing-mode of ECG testing on campus;
- **Ease of learning:** provide intuitive and user-friendly ECG system and guidance, allowing for quick familiarization;
- **Reliability:** ensure the product to be trustworthy;
- **Efficiency:** the device needs to guarantee users to perform an ECG conveniently;
- **Simplicity and clarity:** provide a straightforward and easily understandable user flow;
- **Smoothness:** reduce confusion and minimize user errors;
- **Timely feedback:** give clear and understandable feedback, along with explanations for any errors;
- **Interpretation:** provide necessary knowledge and explanation for professional contents;
- **Youth preference:** incorporate components tailored to the preferences of young people;
- **Interactive channel:** bridge the gap of users and experts;

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APPENDICES

Appendix A - Patents and certificates of D-heart

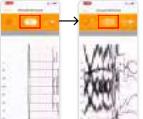
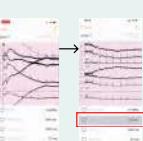
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https://cdn.shopify.com/s/files/1/0653/3290/4160/files/IT324675_CE_MDR_STRENA_MEDICAL_ITA_4.pdf?v=1707388701

Appendix B - Result of Heuristic Evaluation

1. Visibility of system status

Violation	Recommendation	Severity
<ul style="list-style-type: none"> Home page: The feedback about the bluetooth disconnection isn't clear, at the first stage, the user can't understand the error. (so weird without any reasons) 	make the notification of disconnection more obvious and add explanation	3
<ul style="list-style-type: none"> Home page: After clicking the icon of the battery level, it shows a bubble with a confusing icon which looks like Wi-Fi. 		3
<ul style="list-style-type: none"> Exam page: There is no reminder about when to put on the electrode, users may click the 'Start' button without placing electrode. 	Provide a prompt to place the electrodes correctly.	3
<ul style="list-style-type: none"> Exam page: The six icons of loading at the bottom are confusing, they keep running. 		4
<ul style="list-style-type: none"> Exam page: 'Start REC' doesn't seem like a button, but seems like a title, and users thought the recording would start automatically and don't know when to click the button. 		3
<ul style="list-style-type: none"> Exam Report Page: The list of the result is clickable, with a click animation feedback, but there is no change. 	No feedback for the clicking	2
<ul style="list-style-type: none"> Indicator lights are not visible from the user's point of view when worn 		3
<ul style="list-style-type: none"> Home page: When there is a failure of the connection, and appears a 'Try Again' button, users don't know the specific reason why the failure occurs. 		3
<ul style="list-style-type: none"> Home page: When appears a 'Try Again' button, there is a 'search again' button on the right-top, which is not useful and confusing, not any feedback. 		3

Appendix B - Result of Heuristic Evaluation

2. Match between system and the real world

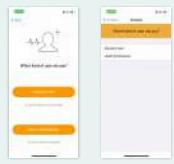
Violation	Recommendation	Severity
<p><i>It's hard to find the entrance to change the language setting.</i></p> 		3
<ul style="list-style-type: none"> • Login-page: 1/all the features are listed with the same spacing 	<p><i>It should divides different sections, using chunking/clusters.</i></p>	3
<ul style="list-style-type: none"> • Login-page: 2/When users want to disable the Touch-ID function, they have to avoid being scanned by the phone camera. 		2
<ul style="list-style-type: none"> • Device-pairing page: The "buy information of the D-heart" is useful but the hierarchy of the information isn't so clear, all the same. 	<p><i>In this stage, users want to focus on connecting with the device, not necessarily on buying the product.</i></p>	3
<ul style="list-style-type: none"> • The information about how to pair the device is useful but it's distracting from the main point why the device is not connected to the app. The texts have the same hierarchy. 		2
<ul style="list-style-type: none"> • Home page: The navigation within the homepage's tools isn't clear, some information are repeated (personal information). 	<p><i>Maybe combine the profile with the setting in the homepage</i></p>	4
<ul style="list-style-type: none"> • Exam page: The feedback of the placement of the electrodes is not obvious. (six icons may change into check mark) 	<p><i>Maybe to give some sound or color feedback to the users.</i></p>	4
<ul style="list-style-type: none"> • General: Only after taking the ECG testing, the user is asked to choose the examinee, why not select the examinee before the testing? 		2
<ul style="list-style-type: none"> • It's hard to fit a mobile phone in the cover slot. 		3

Appendix B - Result of Heuristic Evaluation

3. User control and freedom

Violation	Recommendation	Severity
<p>The lanyard is difficult to unplug from D-heart, which may let users press the switch button by mistake.</p> 		2

4. Consistency and standards

Violation	Recommendation	Severity
<p>The app provides constraints of the password format, but it is covered by the keyboard when inputting password.</p> 		3
<p>The offline mode also asks users to choose user type, but with different buttons from the log-in page.</p> 	<p>Use the consistent buttons to show the same meaning of user type./ Using right sentences to make understand the news steps/</p>	2
<p>Homepage:1. The two Bluetooth messages aren't consistent.</p> 		2

5. Error prevention

Violation	Recommendation	Severity
<p>Exam page: It's hard to switch between female and male, due to the shelter of the box, and ignorance of gender.</p> 	<p>Use a pop-up to remind the user to switch the gender.</p>	4
<p>Neck rope is not good to adjust their own, will need to take off the re-adjustment of the situation, girls do not tie their hair to use it will be more troublesome</p> 		3
<p>The grey circle around the button in the center can be pressed and switched on by mistake (we need to fix this point)</p> 		3

Appendix B - Result of Heuristic Evaluation

6. Recognition rather than recall

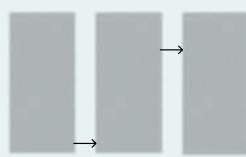
Violation	Recommendation	Severity
<ul style="list-style-type: none"> Home page: The device icon, gives two different messages using the same style, it's hard to understand the difference. 		4
<ul style="list-style-type: none"> Home page: Some important information is hidden. 		4
<ul style="list-style-type: none"> Exam page: Some interacting operations are hidden (edit/share your data). 		2
<ul style="list-style-type: none"> Homepage: The icon of the battery level conveys ambiguous expression, and is hard to know its meaning. 		4
<ul style="list-style-type: none"> Exam page: The icons are too close to the bottom of the interface, which is easily covered by the box. And the 'Restart' button and the switch tab of the gender are in the similar position, which is easily mis-touched. 	Replace the position of the 'Restart' button and the switch tab of the gender	4

7. Flexibility and efficiency of use

Violation	Recommendation	Severity
<ul style="list-style-type: none"> The registration isn't flexible, users need to write again the password information, if they write something wrong. 	When users fill in their personal data, they would be more willing to fill all the data if the app explains to them doing so can help it better analyze their health condition.	2
<ul style="list-style-type: none"> Exam page: The navigation of the calendar and the examinee isn't logical. (The 'ALL' appears twice, which is misleading.) 	Use the 'Tab' to switch calendar and examinee.	3

Appendix B - Result of Heuristic Evaluation

8. Aesthetic and minimalist design

Violation	Recommendation	Severity
<ul style="list-style-type: none"> The Register phase: The information overlaps in the confirm code 		2
<ul style="list-style-type: none"> The Register phase: The error message background is white, which is not distinguishable. 		2
<ul style="list-style-type: none"> Type of user: The choices are not distinct from each other, the icon is not communicating well, and is emotionless. 	Use some visualization & illustrations.	3
<ul style="list-style-type: none"> After choosing the Anonymous Mode, there is a redundant page. 		3
<ul style="list-style-type: none"> Home page: the turn-on-bluetooth notification's background is matte; 	The background can a bit more blur;	1
<ul style="list-style-type: none"> Home page: the icon on the top left corner does not communicate well. 	the blue-tooth connection icon should be more intuitive.	1
<ul style="list-style-type: none"> Exam page: The filter of the different profile images is not obvious. 	Use more contrast.	1
<ul style="list-style-type: none"> Exam page: The transition between the calendar and examinee is unnatural. 		2
<ul style="list-style-type: none"> General: The pages do not communicate graphically with each other, they look like detached parts of the application. 		1

Appendix B - Result of Heuristic Evaluation

9. Help users recognize, diagnose, and recover from errors

Violation	Recommendation	Severity
<ul style="list-style-type: none">The Register phase: the two long texts of the mistake feedback are repetitive. 		4
<ul style="list-style-type: none">During the placement of the electrode, there is no feedback of user's action(right or wrong), not indicating well the steps or suggestions. 		4

10. Help and documentation

Violation	Recommendation	Severity
<ul style="list-style-type: none">Users are asked to figure out the statement of the device based on the LED blinking time. (It's hard for users not only to count the time, but also to remember the rules about the blinking time) 	Some other feedbacks	3

Appendix C - Result of Cognitive Walkthrough

We conducted Cognitive Walkthrough based on following Criteria:

- **Will users try to achieve the right result?** In other words, do users understand that the action (step) at hand is needed to reach their larger goal?
- **Will users notice that the correct action is available?** In other words, is the interactive element that achieves the step visible or easily findable?
- **Will users associate the correct action with the result they're trying to achieve?** Perhaps the right button is visible, but will users understand the label and will they know to engage with it?
- **After the action is performed, will users see that progress is made toward the goal?** Based on what occurs after the action is taken, will users know that this action was correct and helped them make progress toward their larger goal?

1. Set up the app [app]

- S ①Create an account (name, surname, email and Password)
- S ②Input the confirmation code received from e-mail
- S ③Choose the right user (standard user / health professional)
- S ④Fill in personal data & click the button "NEXT"
- S ⑤Fill in health data & click the button "DONE"

2. Set the device [device]

- S ①Assemble the electrodes to the device
- F ②Insert the neck cord into the device
- F ③Turn D-heart on

3. Connect the device via Bluetooth [app]

- F ①turn on the Bluetooth
- F ②press the icon on the left-top
- F ③Press the turn on button in the device
- S ④Read the information to connect the device, press the "begin" button
- F ⑤press to select one device from a list to connect
- S ⑥If the connection fails, press the button 'try again'

4. Place the phone and know the electrode placement(use the camera) [app]

- F ①press the 'Heart' button
- S ②press to select from the two categories
- F ③The camera opens automatically, select the user's gender at the bottom
- F ④Place the phone in the box
- S ⑤Follow the guideline to take a photo automatically

5. Place the D-heart & electrodes, and record the ECG results [device & app]

- S ①Wear D-heart and place the electrodes
- F ②Click the 'NEXT' button to let the D-heart work
- F ③press the "START REC" button to record

6. upload the report & Get the answer from the doctors within 15 minutes [app]

- F ①Choose a patient
- S ②Choose a reason for using ECG
- S ③Press 'Done' button
- F ④Press the "SEND TO TELECARDIOLOGY" button.

F: Failure

S: Success

Appendix D - ConsentForm

Appendix E - Result of Effectiveness

Scenario 1	User 1	User 2	User 3	User 4	User 5	User 6	PE
Subtask 1	E	E	H	H	E	E	83%
Subtask 2	E	E	E	E	E	E	100%
Subtask 3	E	H	E	H	E	E	83%
Subtask 4	F	E	H	F	F	F	25%
Subtask 5	E	E	E	E	H	E	92%
Subtask 6	E	E	H	E	H	H	75%
Subtask 7	E	E	H	H	E	H	75%

Scenario 2	User 7	User 8	User 9	User 10	User 11	User 12	PE
Subtask 1	E	E	F	E	F	E	67%
Subtask 2	F	E	E	H	E	E	75%
Subtask 3	F	H	F	E	H	H	42%
Subtask 4	H	E	F	E	H	H	58%
Subtask 5	E	E	F	H	E	E	75%

Appendix F - Result of Efficacy

Scenario 1	User 1	User 2	User 3	User 4	User 5	User 6	Average
Subtask 1	01:10	01:36	05:04	08:21	03:55	03:06	03:52
Subtask 2	02:18	02:04	02:16	01:38	01:51	02:06	02:02
Subtask 3	01:02	01:51	00:57	01:40	00:45	01:12	01:14
Subtask 4	-	08:03	10:32	-	-	-	09:17
Subtask 5	00:49	00:24	00:46	02:43	01:02	00:59	01:07
Subtask 6	01:30	01:49	00:49	02:21	07:37	01:12	02:33
Subtask 7	01:05	01:08	01:58	02:24	02:06	03:16	01:59

Scenario 2	User 7	User 8	User 9	User 10	User 11	User 12	Average
Subtask 1	01:11	04:42	-	04:13	-	02:48	03:13
Subtask 2	-	05:02	01:58	02:22	02:21	02:53	02:55
Subtask 3	-	04:53	-	01:14	05:47	-	03:58
Subtask 4	00:40	00:13	-	01:49	03:39	04:52	02:15
Subtask 5	00:54	00:39	-	01:48	02:30	00:42	01:19

Appendix G - Result of SEQ and Premo

Scenario 1	User 1	User 2	User 3	User 4	User 5	User 6	Average	Positive	Negative
Subtask 1	6	5	5	6	4	7	5.5	2	4
Subtask 2	6	6	6	6	6	7	6.2	5	1
Subtask 3	6	5	4	7	5	6	5.5	6	0
Subtask 4	6	4	3	2	3	5	3.8	3	3
Subtask 5	5	6	4	3	6	6	5	4	2
Subtask 6	6	5	5	5	2	7	5	3	3
Subtask 7	6	7	4	5	6	5	5.5	6	0

Scenario 2	User 7	User 8	User 9	User 10	User 11	User 12	Average	Positive	Negative
Subtask 1	6	5	6	7	2	7	5.5	2	4
Subtask 2	6	5	6	3	3	6	4.8	3	3
Subtask 3	1	4	2	7	3	7	4	3	3
Subtask 4	6	2	2	5	3	6	4	3	3
Subtask 5	7	6	5	7	6	7	6.3	6	0

---Thank You!---