# Connect in every touch

# Pebbi: Reimagine Emotional Support in Cancer Care
by
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in collaboration with Jiayi Liu

This thesis investigates the design of an integrated wearable-and-app system to address emotional isolation and miscommunication in cancer care. Cancer patients often struggle to express emotional needs, leaving caregivers without the context needed to provide effective support. This project enables patient-led, low-pressure interactions that foster connection without requiring direct conversation. The solution features voice recording, tactile meditation guidance, mood signals, remote "pebbling," and AI emotion mapping, creating a private space for patients' self-reflection while helping caregivers respond with empathy. Iteratively refined based on stakeholder feedback, the outcome emphasizes subtle, context-sensitive support that feels non-intrusive to human interaction and user privacy. The design contributes a new model for emotional care in healthcare technology that prioritizes patient agency, nurtures empathy, and respects authentic connections.

In cancer care, the emotional challenges patients face are often as significant as the physical ones, with many patients experiencing isolation and difficulty articulating emotional needs. These communication gaps, compounded by the sensitive nature of illness, hinder caregivers from providing effective support. Despite advances in medical treatment and digital health solutions, the nuanced emotional needs of patients remain underserved, leading to suppressed feelings and missed opportunities for meaningful connection. This thesis explores how technology can foster empathetic connection and transparency in patient-caregiver relationships while respecting the autonomy of both parties. The research employed a human-centered methodology combining semi-structured interviews, surveys, and in-person observations in cancer care settings, supplemented by extensive literature review and iterative prototyping. Due to ethical considerations, development emphasized alternative validation techniques, including usability critiques and role-playing scenarios with design practitioners and caregivers.

The resulting wearable-and-app system improves emotional transparency and adapts to diverse care contexts. Patients share emotional states through customizable tools like recordings and non-verbal signals, which form a rich emotional journal for caregivers. These insights allow caregivers to respond with empathy and respect for privacy. Features such as mood signals and "pebbling" cues enable non-intrusive yet meaningful interactions that strengthen understanding, even at a distance. Additionally, AI-enhanced emotion mapping provides insights into emotional trends, fostering a more nuanced, shared awareness of the patient's journey. The project faced key limitations in direct patient testing and the challenge of balancing interface simplicity with emotional complexity. Through iterative refinement based on stakeholder feedback, the system prioritizes adaptability and non-intrusive interfaces, respecting individual boundaries and the often shifting dynamics of illness. The final design emphasizes low-pressure, patient-led interactions and serves as a flexible framework that encourages self-reflection, emotional grounding, and subtle, supportive exchanges.

The thesis contributes a model of healthcare technology that empowers patients, nurtures empathy, and positions technology as a subtle enabler of human connection. Future opportunities include expanding the system's adaptability for diverse chronic illness contexts, enhancing personalization capabilities, and exploring peer support possibilities while maintaining privacy boundaries. By blending patient-centered design, affective computing, and adaptive interaction, this project proposes a new approach for future applications of emotional care in healthcare, with implications that reach beyond the context of cancer care alone.

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# Introduction

Cancer care is not only a physical challenge but also an emotional journey marked by profound struggles for both patients and caregivers. For patients, the illness often brings a shifting self-image as they navigate physical changes [1, 2], emotional volatility, and a loss of independence. Many patients and caregivers grapple with guilt over how their emotions impact each other, leading them to suppress their true feelings or adopt a facade of positivity, deepening feelings of isolation and emotional disconnect [3, 4].

This thesis addresses these challenges by investigating how design can support more empathetic, transparent, and adaptable communication between patients and caregivers. Guided by the question, "How can technology foster emotional connection while respecting boundaries and preserving the authenticity of human relationships?" this research explores tools that empower users to share their emotional states in intuitive and non-intrusive ways.

# How can technology foster emotional connection while respecting boundaries and preserving the authenticity of human relationships?

While primary caregivers, such as close family members, are often deeply involved in a patient's journey, many patients also seek care and acknowledgment from a broader secondary support network, including friends and extended family. However, limited energy, physical vulnerability, and emotional strain make these interactions challenging. Patients are often caught between a desire for connection and a need for privacy. At the same time, caregivers face the challenge of balancing emotional labor with practical responsibilities [5], often without adequate access to professional psychological guidance on supporting patients and themselves through difficult circumstances [6]. This dynamic frequently results in miscommunication and misaligned expectations, with even well-meaning interactions sometimes causing unintended emotional tension.

With the complexities and the deeply sensitive nature of cancer care in mind, this thesis explores the nuanced and evolving nature of emotional communication in patient-caregiver relationships. It seeks to inform the design of technology that fosters empathy and understanding without demanding excessive effort. Through careful consideration of personal boundaries and emotional transparency, the work aims to empower both patients and caregivers to navigate their shared emotional journey with greater ease and authenticity.

# Background

The emotional dimension of cancer care has gained increasing attention in recent years as researchers and practitioners recognize its profound impact on recovery outcomes, patient quality of life, and caregiver well-being. A meta-analysis by DiMatteo et al. [7] revealed that depressed patients were three times more likely to be non-compliant with medical treatment, especially affected by factors like hopelessness and reduced social support. This relationship between psychological state and treatment adherence was further established in cancer care specifically [8, 9]. While various screening tools have been developed to assess distress [10], the Institute of Medicine's comprehensive report [11] identified a more fundamental requirement: developing systematic approaches to facilitate effective emotional communication and psychosocial support.

## 2.1 Monitoring Systems

Technological advancements in cancer care reflect this growing recognition, though early solutions focused primarily on symptom tracking and clinical management. While remote monitoring systems documented by Aapro et al. [12] improve clinical oversight, they often fail to address patients' emotional needs. Similarly, current cancer support applications largely prioritize practical aspects, such as medication management and appointment scheduling, with limited attention to deeper emotional communication [13].

## 2.2 Mental Health Initiatives

Even mental health-focused approaches reveal gaps in addressing the complexity of emotional support. Marshall-McKenna et al. [14] found that while existing platforms excel at logistical care, they struggle to facilitate meaningful emotional communication between patients and their support networks. Badr et al. [15] demonstrated that addressing the emotional needs of both patients and caregivers simultaneously yields better outcomes, yet few solutions adopt this integrated approach. Kent et al. [16] further highlighted that current systems often fail to address the interconnected emotional needs of patients and caregivers, especially in facilitating mutual understanding of each other's emotional states.

## 2.3 Approaches and Frameworks

The communication gap in existing solutions extends beyond functionality to fundamental design approaches. Shahsavar and Choudhury [17] identified distinct patterns in how emotional distress and support preferences evolve over time, with newly diagnosed patients showing different needs compared to long-term survivors. Their study highlighted the roles of personal health perception and self-care ability in emotional well-being. Solberg et al. [18] documented similar patterns in caregiver experiences, suggesting that support tools should account for different phases of the cancer journey. This understanding of the temporal and dynamic nature of emotional support needs reveals a critical limitation in existing technologies that tend to offer static, one-size-fits-all approaches to emotional communication.

Several theoretical frameworks inform potential solutions. Engel's

biopsychosocial model [19] emphasizes the interconnection between physical health and psychological well-being, while Gross's emotion regulation model [20] provides insights into emotional expression. The Technology Acceptance Model [21] highlights that perceived usefulness and ease of use are crucial for successful implementation.

## 2.4 Gaps in Current Projects

Current research also uncovers opportunities for advancement and areas of caution. A comprehensive analysis of mobile health applications by Dehling et al. [22] emphasizes the critical challenge of balancing privacy with accessibility, particularly in applications handling sensitive emotional and health data. Zon et al. [23] further highlight the importance of context awareness in healthcare systems, noting that current systems often lack the ability to adapt to varying emotional states and environmental contexts. Addressing these gaps requires thoughtful solutions that can dynamically respond to the evolving needs of patients and caregivers across diverse settings.

These insights from existing literature and current technological solutions inform the development of more holistic, integrated approaches to emotional support in cancer care. By addressing patient and caregiver needs simultaneously, maintaining privacy, and fostering authentic emotional expression, new systems can create more empathetic and effective models for emotional care.

# Motivation

### 3.1 Critical Emotional Support Need

This project is primarily motivated by the critical need to address the underserved emotional well-being of cancer patients. While there have been significant improvements in physical cancer treatment, the emotional toll on patients from diagnosis to post-treatment is often overlooked. Having witnessed family members undergoing the emotional burdens of cancer, I saw how unaddressed mental health issues led to rapid physical and emotional deterioration. Emotional gaps can lead to decreased adherence to treatment, reduced resilience, and poorer long-term outcomes.

### 3.2 Complexity of Emotional Challenges

The emotional challenges faced by cancer patients are not only severe but also complex. They experience a spectrum of emotions—anxiety, fear, frustration, uncertainty, isolation, hope, and sometimes outbursts of anger. Factors like fatigue, pain, and other uncontrollable biological aspects can intensify emotional volatility and unpredictability. For patients who are physically weakened, emotionally drained, and increasingly dependent on caregivers, being fully aware of and articulating emotional needs becomes even more difficult. Consequently, there is often a disparity between what patients feel and what they convey to others. This gap can lead to misinterpretations or a lack of emotional care altogether, causing distress for both patients and those supporting them.

### 3.3 Healthcare System Constraints

Meanwhile, healthcare professionals and caregivers struggle to provide adequate emotional attention when burdened with overwhelming responsibilities, limited time, and insufficient resources. The medical and logistical aspects of care leave little room for the sustained, empathetic communication that patients so often require, which can leave patients feeling mentally alienated. Existing care models and systematic limitations often fall short of addressing these deeper, more personal struggles.

### 3.4 Technological Opportunity

The convergence of rising awareness and technological capability presents an opportunity to address the gap. The broader shift in healthcare that increasingly acknowledges the role of mental health makes the project timely. It has become clear that focusing solely on physical treatment is insufficient for long-term recovery. Meanwhile, advances in biosensing technologies and AI-driven health tools have made it possible to develop personalized real-time emotional monitoring and feedback that adjusts to each patient's unique needs. Nonetheless, there are still limited tools available that provide continuous, tailored emotional support for cancer patients.

### 3.5 Design Approach

This project critiques existing emotional support tools—many of which are generalized apps that fail to consider the specific, nuanced emotional needs of cancer patients.

Aiming to offer a more tailored and context-sensitive solution, it assists patients throughout the cancer journey. Moreover, it proposes to provide patients with a proactive way to not only recognize and reflect on their subtle, fluctuating emotional states but also develop strategies to express emotional needs for support and understanding. By fostering patients' relationships with themselves and with others, the project promotes patient agency, empowering them to navigate the emotional complexities of cancer and adapt to their ever-changing relationship with cancer.

As a design thesis, this project sits at the intersection of user-centered design, empathy-driven technology, and healthcare innovation. It pushes the boundaries of traditional healthcare design by integrating emerging technologies with emotional intelligence. The project also aligns with the broader goals of design education by demonstrating how design can address complex, emotionally charged challenges with innovative and compassionate solutions.

## 3.6 Broader Healthcare Impact

Looking at the broader impact, the project aims to reshape how emotional well-being is integrated into the cancer care experience. It seeks to reduce the risk of chronic mental health issues, such as anxiety and depression, that often persist prolonged post-treatment. The tool can also foster stronger relationships and more effective communication by improving emotional transparency between patients, caregivers, and healthcare providers. This project proposes a shift in the healthcare paradigm toward a more proactive, patient-centered model that prioritizes emotional health for better overall health outcomes.
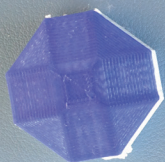
## 4.1 Design Framework

At the heart of the project's approach lies the belief that a practical, empathetic solution must be deeply informed by the emotional complexities cancer patients face across each stage of their journey. By employing human-centered design, systems thinking, and a patient-centered framework, we maintained focus on patients' needs while remaining responsive to the diverse, emotionally charged contexts they navigate [24].

## 4.2 Research and Data Collection

Our research began with an intensive qualitative data-gathering phase involving cancer patients, caregivers, and healthcare providers. Through 6 semi-structured interviews, 31 online surveys, and in-person observations in a cancer care department, we identified core patient challenges, including isolation, difficulty with self-expression, and a strong need for empathy and emotional support. Although limited in number, these firsthand accounts provided depth and valuable insights into patient experiences. Secondary research supplemented these findings with a focused review of literature, case studies on mental health interventions, and analyses of public datasets on patient behavior. These insights shaped a design approach to fit real-world settings and answer real struggles.

## 4.3 Systems Analysis and Stakeholder Mapping

Complementing this focus on individuals, we applied systems thinking to understand how a patient's journey spans hospital visits, at-home care, and digital communication touchpoints. Using business origami, we visualized the complex web of relationships between patients, caregivers, healthcare providers, and support networks. This technique proved particularly valuable in identifying critical communication patterns and emotional touchpoints within the cancer care ecosystem, revealing opportunities for meaningful intervention. The mapping also highlighted how different stakeholders' needs and behaviors shift throughout the cancer care journey, informing our approach to creating adaptive support mechanisms.



Figure 1. Business Origami Mapping the Cancer Care System

## 4.4 Communication Model Design

Building on these insights, we modeled a communication system that addressed the identified pain points in patient-caregiver relationships, particularly focusing on moments when emotional support was most needed but hardest to express. This model emphasized non-intrusive ways of maintaining connection while respecting patients' need for autonomy and privacy during vulnerable moments. We paid special attention to creating a system that could adapt to different levels of emotional capacity and physical energy, recognizing that patients' needs and abilities fluctuate throughout their treatment journey.

## 4.5 Iterative Development and Testing

The design development progressed through multiple stages of prototyping and testing, each focusing on refining different aspects of the user experience. Early prototypes explored various form factors and interaction methods. Through 8 collaborative sessions with both patients and design practitioners, we continuously refined the device's physical design, interaction patterns, and emotional communication features. Feedback from these sessions was instrumental in shaping key features such as the tactile feedback system, color-based caregiver signaling, and the overall form factor of the device. These findings helped ensure that the final design would be both functionally effective and emotionally resonant for users while remaining adaptable to different contexts and personal preferences.

Combining research, creative pro-totyping, and a systems-aware ap-proach, this thesis project was ground-ed in empathy, developing a solution that could thoughtfully and mean-ingfully support patients' emotional well-being while also offering a tool for caregivers to navigate together with sensitivity and care.
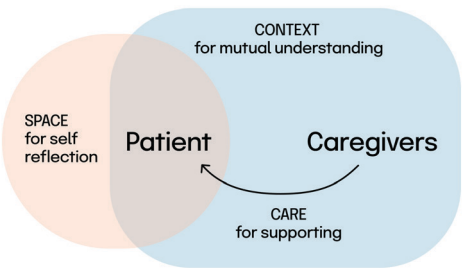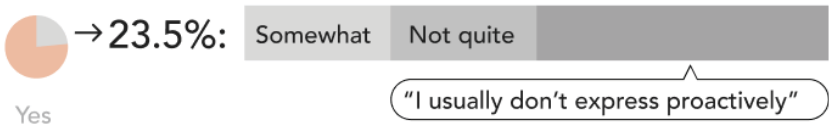


Figure 2. Communication Model

## PATIENTS

**Middle-aged and elderly cancer patients with mild to moderate severity,** navigating between hospital treatment, support from family caregivers, and balancing work and daily life responsibilities.
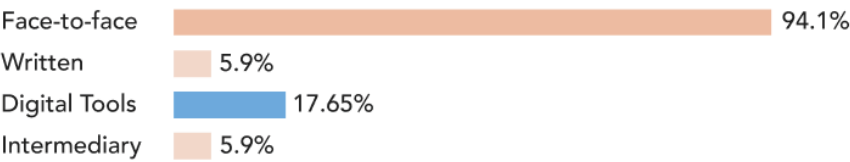
## CAREGIVERS

| | 76.5% |
|---|---|

Self-care — Family Member

## Do caregivers understand and respond well to your emotional needs?

→ 23.5%: Somewhat | Not quite

Yes

"I usually don't express proactively"

## Which methods do you feel are most helpful?

Face-to-face — 94.1%
Written — 5.9%
Digital Tools — 17.65%
Intermediary — 5.9%

## What kinds of emotional support and communication would you like?

Open & honest communication

Express myself freely without worrying about bothering them.

Companionship

They can better understand my emotions before rushing to provide solutions

Encouraging me to express my emotions freely without judgment

Frequent check-ins on my emotional state and needs

Proactively helping with daily tasks

Patient listening

Figure 3. Interview and Survey Findings
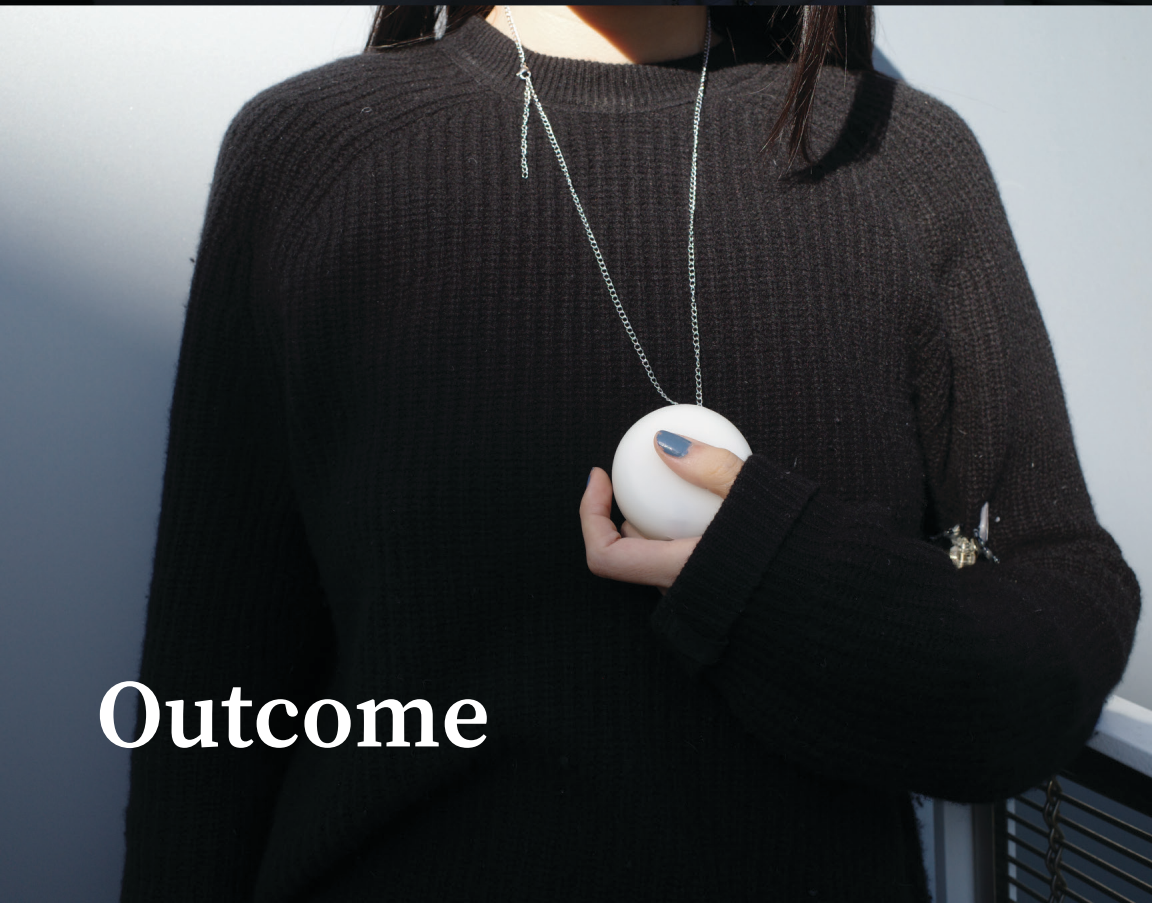
Outcome

This project presents a personalized emotional support device paired with a companion app name Pebbi, supporting patients in managing emotional fluctuations and providing a channel for emotional expressions throughout their cancer journey. This tool seeks to mitigate miscommunications arising from the lack of context and transparency. Through intuitive, patient-led interactions, this device-and-app system empowers patients to share and track their emotions with caregivers.

## Device to App

Pebbi's core component is a compact, Bluetooth-enabled device built around a microcontroller with integrated sensors. Its biocompatible silicone exterior is waterproof and durable for daily use. Key features include haptic feedback, LED indicators, pressure sensors, an inertial measurement unit, a microphone, and a battery providing two days of continuous operation.

**Hardware**

Core controller
Seeed Studio XIAO nRF52840 Sense

Power Management
500mAh Rechargeable Lithium Polymer Battery

Voice Input
On-board Pulse Density Modulation Microphone

Movement Sensor
On-board 6-axis Inertial Measurement Unit

Haptic Feedback
DRV2605L

Visual Indicator
Neopixel LED

Touch Input
Force Sensor

**Connectivity**

Wireless
Mbed-Enabled Bluetooth

Integration
Secure Pairing

**Application**

User Interface
Patient Dashboard    Caregiver Portal

Data System
Storage and Sync    Privacy Management

AI Features
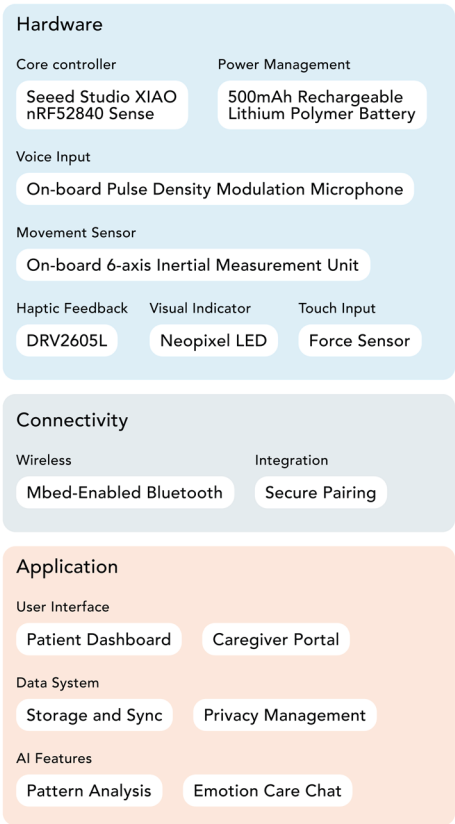Pattern Analysis    Emotion Care Chat

Figure 4. System Structure



Figure 5. Hardware Implementation

Pebbi offers both automatic and self-initiated check-ins. At preset times, it gently prompts users with five pulses of light and vibration. Users can also initiate check-ins by pressing the device for a second, which activates the logging process. When patients want to record their emotional state, they long press the device. The pressure intensity determines the emotional signal strength, with the LED gradually brightening in response. Two blinks and gentle vibrations confirm when the log is complete.

The voice-recording feature enriches emotional expression, allowing patients to document experiences privately. Flipping the device starts recording, confirmed by a white light and double vibration. A second flip ends the session, with two blinks confirming the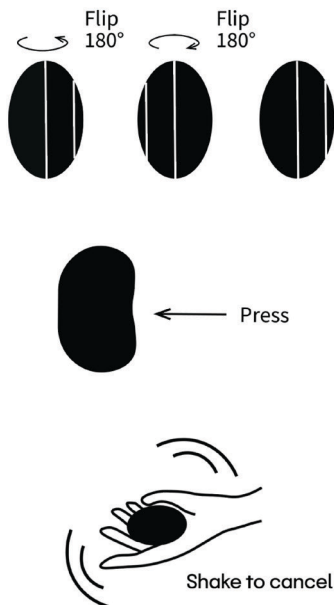 save. If they wish to cancel, a simple shake stops the recording without saving. This creates a personal space for self-awareness and expressive practice without the pressure of immediate external expressions and confrontations.

Each interaction is logged in both patient and caregiver apps, creating a chronological emotional map accessible at their convenience. The app presents this data in an accessible format, allowing patients to track their emotional patterns over time.

The app also includes an AI-assisted feature that helps caregivers interpret the emotional data and suggests appropriate ways to respond - whether by giving space, offering comfort, or simply being present. This guidance helps maintain meaningful connections while respecting the patient's emotional state and need for autonomy.
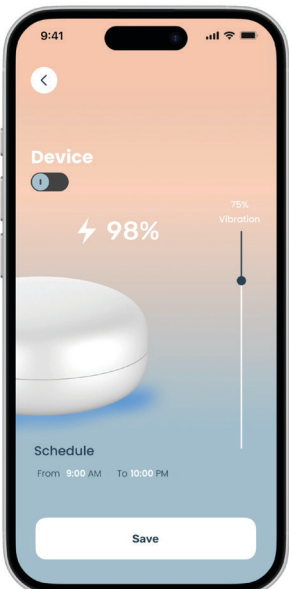


Figure 6. Interaction Controls



Figure 7. App Interface for Adjusting the Device

Figure 8. Subtle Lights Indicating Caregivers' Pebbling Messages



Figure 9. Patient's Emotional Map - Day View on the Caregiver's App

## App to Device

For self-calming practice, patients can initiate meditation sessions from the app's library, syncing breathing guidance with the Pebbi's light and vibration patterns to ground emotions.

Besides passive observation, the app enables caregivers to actively engage with the patient's emotions through the "pebbling" function. These gentle reminders can come from multiple caregivers, each with their unique colored light paired with vibration patterns that the patient can customize.

This form of reassuring, low-pressure reminder reminds the patient that caregivers are attentive, reinforcing
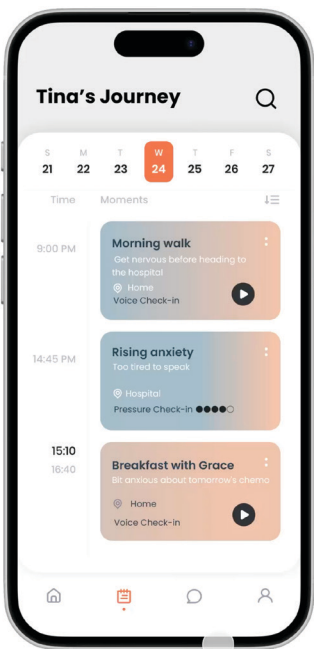
emotional bonds even when physically distant. This subtle pebbling is particularly valuable when patients feel isolated or wish for acknowledgment without direct interaction. The bidirectional communication through the device and app nurtures understanding and emotional closeness, setting the stage for authentic, empathetic in-person interactions.

Throughout the day, this system creates a subtle but continuous channel for emotional support and connection. When patients need to focus on activities like online meetings or family time, they can easily adjust or pause notifications, maintaining control over their level of engagement while staying connected to their support network.

## Iterative Design Process

In early prototypes, we included a range of gesture controls and tracking metrics, including biosensors, but patients preferred simpler, less overwhelming interactions. This led to easy-to-use features like squeeze-activated vibrations and single-function controls. To protect privacy and avoid intrusive GPS tracking that provided limited context, we integrated recording to encourage patients to share relevant details proactively. The final design prioritizes voice and pressure logs, balancing information depth and usability to support transparent, empathetic communication. This outcome combines functionality and emotional relevance to enhance quality emotional care for cancer patients.



Figure 10. Pebbi User Manual

# Discussion

# Discussion

Technology in healthcare often walks a fine line between providing support and maintaining human connection. Through our development and testing process, we identified several critical factors that influence the success of such interventions.

## 6.1 Empowering, Not Replacing

An essential insight from the project was recognizing the value of trusting patients and caregivers to initiate and sustain meaningful communication on their own. By stepping back from inserting technology into in-person exchanges, the device provided a supportive framework that encouraged natural empathy without direct intervention.

This approach treated technology as an "invisible facilitator," preserving the authenticity of patient-caregiver connections. It has broader implications for healthcare and mental wellness technology, which can evolve to support autonomy and authenticity, encouraging the development of context-aware and flexible tools rather than intrusive and prescriptive.

## 6.2 Adapting for Emotional Nuance

Feedback from patients and caregivers underscored the need for adaptability. While users appreciated features like quick mood logging with pressure input, some patients found certain physical interactions challenging during periods of fatigue. To address this, we implemented customizable pressure sensitivity, allowing patients to personalize how the device interprets their interactions. They could set whether a firm press indicates high stress or low stress, adapting to their natural patterns and energy levels. Design practitioners suggested enhancing the device's visual communication through ambient light indicators, where different colors could help caregivers immediately understand patients' needs in shared spaces. For instance, using purple signals a desire for privacy while green indicates openness to connection. This balance between accessibility and depth became a recurring theme. While streamlined features enabled quick self-expression, they sometimes oversimplified patients' complex emotional states where feelings such as "hopeful yet anxious" coexist.

The voice-recording feature highlighted another dimension of this challenge, as patients' comfort with verbal expression varied significantly. Some found the guided, private recordings empowering, while others felt uncertain about articulating nuanced feelings. Future iterations could explore more adaptable recording approaches, such as conversational AI that offers gentle prompts without directing responses. Adaptive recording modes could offer a choice between guided reflection, open journaling, or even structured prompts, adding flexibility to the tool and encouraging self-reflection without imposing a rigid structure.

## 6.3 Holding Space for Connection

The pebbling feature underscored the impact of low-pressure, non-contact communication in providing a steadying, supportive presence. This form of communication respects patients' boundaries as they navigate shifting self-images and emotions,

especially during moments of heightened emotional vulnerability and physical conditions when they feel more private and prefer to avoid interactions.

Our current implementation includes distinct patterns for different caregivers, each with unique light colors and vibration rhythms. While effective, user testing revealed opportunities to further refine these interaction cues. Future iterations could explore carefully curated preset patterns that maintain intuitive interaction while subtly conveying different levels of urgency or types of support.

## 6.4 Technical Limitations and Future Work

Several limitations emerged through our development process. Current AI emotion recognition systems still face challenges in accurately interpreting nuanced emotional states, particularly in healthcare contexts. Cultural differences in emotional expression also present opportunities for further development, as communication patterns vary significantly across communities. Additionally, our testing with 8 participants forms a small sample size that restricts the generalizability of our results and suggests the need for broader validation studies.

## 6.5 Visualizing Impact

Our testing revealed distinct patterns in system usage throughout daily routines. Morning check-ins typically focused on physical state assessments, while evening recordings included more emotional reflection. Patients initiated more connections during treatment days, while caregivers increased their "pebbling" support during recovery periods. These patterns suggest that emotional support needs follow predictable cycles that could inform future healthcare technology design.

# Conclusion

# Conclusion

This thesis has demonstrated how thoughtfully designed technology can address the emotional communication challenges of cancer patients and their caregivers and empower both parties to navigate their shared journey with greater empathy and understanding. By prioritizing patient agency and designing for subtle, low-pressure interactions, the wearable-and-app system effectively bridges communication gaps while respecting individual boundaries and the complexities of emotional expression. Tools like reflective voice recordings, tactile meditation guidance, mood signals, and AI emotion mapping allow patients to express emotions in adaptable ways, while caregivers benefit from subtle cues like pebbling, helping them provide tailored, empathetic support. Together, these tools facilitated greater empathy and understanding, improving the quality of emotional care without replacing in-person interactions.

The project's primary contribution lies in demonstrating how technology can serve as a responsive companion rather than an overseer. Cancer patients often contend with diminished autonomy, making the freedom to initiate sharing a defining feature of this tool. In contrast with monitoring-driven tools, this model positions the patient as an active participant in their care, reframing wearable technology as enablers rather than monitors. It empowers patients to communicate on their terms without presuming to predict or interpret emotional states, instead allowing users to decide what, when, and how to communicate.

This reframed relationship between patients and technology promotes patient agency and respects their self-determination, recognizing the deeply personal journey many undergo in navigating chronic illness, self-acceptance, and self-reconciliation.

Future research could expand the system's adaptability to support diverse patient needs or chronic illness contexts. Enhancing personalization features could deepen the emotional resonance of such tools. Additionally, more directions can be explored, such as how similar systems might facilitate broader community support among patients with shared experiences in a way that preserves privacy and boundaries.

Beyond cancer care, this project demonstrates the value of designing healthcare technology that respects patients as whole individuals with complex emotional needs and personal preferences. As healthcare continues to embrace digital solutions, maintaining this balance between technological capability and human agency becomes increasingly critical. Success in this domain requires understanding that true innovation in healthcare technology isn't just about monitoring and managing conditions—it's about empowering patients to navigate their health journey with dignity, agency, and meaningful human connection at the heart of care.

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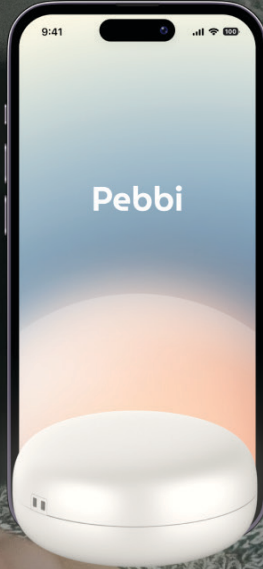
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