Inclusive Design for Dairy Spoilage Detection: Supporting Users with Olfactory Impairments

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Abstract

This Major Research Project explores how inclusive design can support everyday food safety decision-making for individuals with olfactory impairments and broader user groups. The project began from a practical concern: when smell cannot be relied upon, assessing whether food is safe to consume can become uncertain, dependent on others, and potentially risky. Focusing on dairy products as an initial context, this study examines how spoilage assessment might be translated into an affordable, user-friendly, and accessible interaction experience. Rather than developing or validating a scientifically precise spoilage detection technology, this research is positioned as a design-led study focused on interaction, usability, and user interpretation. Grounded in inclusive design and the knowledge loop framework, the project synthesizes literature on olfactory impairment, dairy spoilage mechanisms, existing detection technologies, tangible product interaction, and multimodal feedback. These insights informed the development of a prototype system consisting of a handheld physical device, sample preparation components, functional simulation, and a supporting mobile application. User testing and survey methods were used to examine how participants understood, operated, and interpreted the prototype system. The findings indicate that multimodal feedback was generally understandable, especially when system states were communicated through coordinated visual, auditory, and vibrational cues. However, the sample preparation and physical setup stages introduced notable interaction challenges, including uncertainty around measurement, assembly, containment, and coordination between the device and application. The project contributes design insights and recommendations for future iterations of food spoilage assessment tools. It argues that beginning with the needs of users who cannot depend on smell can reveal broader opportunities for designing supportive, understandable, and inclusive systems for everyday food-related decision-making.

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1.0 Introduction

1.1 Background and Motivation

Individuals with sensory impairments face distinct challenges in everyday life, among which food safety represents a particularly critical concern. This issue is not only theoretical but deeply personal. My mother, who was born with a congenital olfactory impairment, has long struggled to detect food spoilage and has relied on others to determine whether food is safe to consume. Growing up, I often assumed this role by assessing food through smell on her behalf. This experience revealed that olfactory loss is not merely an inconvenience, but a persistent and potentially dangerous limitation in everyday life.

The urgency of this issue has been significantly amplified in recent years. The COVID-19 pandemic brought wider public and clinical attention to smell dysfunction, as chemosensory impairment has been recognized as one of the main clinical presentations of COVID-19 (Ivona & Cortés Vega, 2021, p. 1). At the same time, recovery is not always immediate or complete, with many individuals reporting long-term or incomplete recovery (Schwab et al., 2021, pp. 5–6). In addition to long-term cases, temporary smell impairment caused by colds, allergies, or sinus infections can also expose individuals to similar risks. In these situations, people may unknowingly consume spoiled food due to the absence of reliable sensory cues, this clinical research further demonstrates that olfactory impairment directly affects individuals' ability to detect food spoilage. Studies have shown that people with smell disorders are significantly more likely to experience food-related safety risks, including difficulty detecting spoiled food, and broader safety-related concerns in daily life (Miwa et al., 2001, pp. 497, 500–502).

In this project, individuals with olfactory impairments serve as the primary point of entry, while the resulting design aims to support a wider range of users who may encounter temporary or situational sensory limitations.

Inclusive design provides a valuable framework for addressing accessibility issue such as olfactory impairments by shifting the focus of design from products to users. Rather than requiring users to adapt to predefined functional or aesthetic constraints, this approach emphasizes understanding a wider range of user capabilities from the outset of the design process (Clarkson et al., 2003, p. 94-95). Beginning with the needs of individuals who are often excluded and extending these solutions to a broader population, inclusive design enables more adaptable and widely applicable outcomes.

To ensure feasibility and focus, this research centers on dairy products as the initial category of investigation. Dairy items such as milk, yogurt, and cheese are relevant because spoilage in this category is often associated with odor-related changes and volatile compound formation. In particular, milk provides a well-supported starting point, as off-odors are often among the earliest indicators consumers have of milk spoilage (Silcock et al., 2014, pp. 81). This makes them especially challenging for individuals with olfactory impairments and therefore a meaningful starting point for design exploration. While the immediate scope is limited to dairy, the broader goal is to develop design principles that can be extended to other food categories.

1.2 Research Gap

Despite the availability of various consumer-facing solutions, existing approaches to food safety often do not directly assess the actual condition of food. Instead, many rely on indirect strategies such as tracking, monitoring, and prediction. For example, smart refrigerator systems such as Samsung's Family Hub use internal cameras and AI-based recognition to identify and track stored food items, providing reminders based on estimated expiration timelines rather than real spoilage conditions (Wiggers, 2020). Similarly, mobile applications such as NoWaste allow users to manually record purchase dates and receive expiration-based notifications (NoWaste, n.d.).

This reliance on indirect indicators extends across different types of solutions. Some systems estimate freshness based on external factors such as time, storage conditions, or user-recorded data, which may not accurately reflect the actual state of food, particularly in everyday situations where items have been opened, transferred, or partially consumed. Other approaches attempt to improve usability by embedding freshness feedback directly into packaging. For example, Mimica's Bump is a temperature-sensitive packaging indicator available as a cap or tag. Users assess freshness by touching its surface: when it feels smooth and firm the product is still fresh, while the emergence of raised bumps indicates that it should no longer be consumed (Mimica, n.d., "How to use Bump" section). While these solutions offer a more immediate and direct form of feedback at the point of use, they remain constrained by specific packaging formats and product types and therefore cannot be readily applied to the broader range of food conditions encountered in domestic contexts. At the same time, more direct detection methods do exist in laboratory and industrial settings, where devices can measure chemical or microbial indicators of spoilage. However, these systems are typically associated with higher costs, specialized operation, and the need to interpret technical data. For instance, commercial water activity meters are generally presented as instruments for production, quality control, and laboratory settings, which limits their accessibility for everyday household users (AQUALAB, n.d., "Designed for production, QA, and R&D" section).

Taken together, these observations suggest that the issue is not simply the absence of tools, but a mismatch between existing solutions and the realities of everyday food use. There is a lack of accessible and practical approaches that allow users to directly and independently assess food conditions in real time. This gap becomes particularly significant for individuals who cannot rely on sensory cues such as smell.

1.3 Research Question

In response to the gap identified above, this study explores how design approaches can better support independent and reliable food safety decision-making in everyday contexts. More specifically, it takes the needs of individuals with olfactory impairments as a starting point and investigates how an inclusive design approach can inform the development of a system that not only addresses these needs but can also extend benefits to a broader range of users.

The primary objective of this study is to examine how inclusive design can inform the development of an affordable and user-friendly system for supporting dairy spoilage assessment, with a focus on interaction, usability, and user experience rather than the development of new sensing technologies. This research aims to translate existing knowledge about food spoilage, sensory limitations, and design guidelines into a practical and accessible design solution.

More specifically, this project pursues three objectives. The first objective is to synthesize insights from literature and existing practices, including food spoilage mechanisms, sensory impairments, and inclusive design approaches, in order to inform design decisions and identify key considerations for usability and accessibility. The second objective is to develop and iteratively refine a prototype system by integrating ergonomic design, multi-sensory feedback, and interaction workflows. The third objective is to generate user-centered insights through a combination of prototype testing, interviews, and exploratory surveys, in order to understand how different users perceive, interpret, and engage with food-related tools in everyday contexts. These insights are further analyzed to inform iterative improvements to the design.

Based on these objectives, this study is guided by the following research questions:

Core Research Question

How can an inclusive design approach inform the development of an affordable and user-friendly system for supporting dairy spoilage assessment for individuals with olfactory impairments and broader user groups?

Support-questions

RQ1. How can an inclusive design approach guide the translation of food spoilage assessment into an accessible and user-centered interaction experience?

RQ2. How do different users perceive and interact with a spoilage assessment prototype, and what insights can their feedback provide for improving usability and accessibility?

1.4 Scoping and Positioning

This study is positioned as a design-led research project that focuses on interaction, usability, and inclusive user experience, rather than the development or validation of new sensing technologies. While the prototype incorporates a simplified sensing mechanism to simulate the process of food spoilage detection, the purpose of this implementation is not to establish accurate or scientifically validated detection results. Instead, it serves as a means to explore how food spoilage assessment can be experienced, interpreted, and acted upon through design. Accordingly, this research does not aim to evaluate or optimize detection accuracy, nor does it attempt to contribute directly to advances in food science, chemical analysis, or sensor engineering. The technical components used in the prototype are employed primarily as representational tools to support interaction design and user testing.

Within this positioning, the study takes the needs of individuals with olfactory impairments as its starting point, but does not treat this group as the sole boundary of the design. Instead, the research adopts an inclusive design perspective in which the initial point of departure is a group whose needs are often insufficiently addressed, while the resulting design is intended to inform broader usability across users with different sensory abilities, physical conditions, habits, and everyday experiences. In this sense, the project is not framed as a specialized solution only for one narrowly defined group, but as an exploratory design study that begins from a specific form of exclusion and investigates how the resulting insights may extend to a wider range of users over time.

The scope of the project is further constrained in order to maintain feasibility and clarity of focus. First, the study concentrates on dairy products as a specific and manageable context for design exploration. While the prototype simulates spoilage detection through gas sensing, the system does not establish or validate actual thresholds for dairy spoilage. Instead, the emphasis is placed on how users interact with the device and application, how feedback is communicated, and how design can support independent decision-making in everyday situations. Second, the system is positioned as a supportive tool that provides indicative feedback rather than definitive judgments about food safety. This distinction ensures that the design remains aligned with its intended purpose as an assistive decision-making aid, rather than a replacement for expert evaluation or laboratory testing.

The extent of iteration within this study is also intentionally limited. Although the broader design framework adopted in this research supports ongoing cycles of refinement and expansion, the present study concludes after the development of an initial prototype and the generation of a subsequent layer of user-informed insights, rather than proceeding to a fully developed second iteration. This decision reflects the exploratory nature of the project, which prioritizes the identification and interpretation of design opportunities over the completion of a finalized product. At the same time, this limited scope provides a structured foundation for future iterations, in which the prototype, findings, and methodological approach can be extended and further developed. The design framework and the scope-related implications of this positioning will be discussed in greater detail in chapter 2.2.

2.0 Conceptual Foundation

This chapter outlines the conceptual foundations that inform the development of this study. Rather than functioning as a comprehensive literature review, it selectively brings together the key knowledge, frameworks, and design considerations that support the direction of the research. It first establishes the problem and technical context by examining food safety decision-making in relation to olfactory impairment, dairy spoilage mechanisms, and existing food spoilage detection approaches and technologies. It then introduces the inclusive design perspective and the knowledge loop as the framework guiding how these insights are translated into the structure of the study. Finally, it identifies the main design considerations that inform the development of the proposed system, including both physical and interaction-related factors. Together, these foundations establish the basis for the research methods and prototype development discussed in the following chapters.

2.1 Problem and Technical Context

This section establishes the problem and technical context that frames the study. It first examines how everyday food safety decision-making becomes difficult when olfactory information is unavailable, then considers the mechanisms through which dairy spoilage can be understood, and finally reviews existing approaches and technologies for food spoilage detection. Together, these perspectives define both the practical problem addressed by the study and the range of technical directions relevant to its development.

2.1.1 Olfactory Impairment and Food Safety Decision Making

Olfactory ability plays a critical role in everyday life, particularly in relation to food perception and safety. Beyond its contribution to flavor and appetite, the sense of smell also supports warning and protection from environmental hazards, including spoiled or unsafe food (Boesveldt & Parma, 2021, pp. 559–560). In everyday food-related decision-making, people often rely on a combination of sensory cues and prior experience to judge whether food is still safe to consume. Sensory evaluation literature emphasizes that food products are perceived through multiple sensory channels, including sight, smell, taste, touch, and hearing, and that responses to food are shaped by the interaction of these sensory messages rather than by a single isolated cue (Stone & Sidel, 2004, pp. 13–16). Smell is therefore one important source of information within this broader sensory judgement process.

This process becomes significantly more difficult when olfactory information is unavailable or unreliable. For individuals with olfactory impairments, the loss or distortion of smell removes one of the most important cues for recognizing changes in food condition. As a result, decision-making around food safety can become uncertain, especially in situations where users must rely on judgment rather than clearly visible evidence. In response, individuals may turn to alternative strategies such as checking expiration dates, relying on visual appearance, or seeking confirmation from others. However, these approaches often provide only partial guidance and may not fully address the absence of reliable olfactory information.

A growing body of research shows that olfactory impairment affects food safety decision-making in practical and significant ways. Studies have shown that smell loss is associated with increased difficulty in detecting spoiled food and broader disruptions to eating-related behavior, including changes in food enjoyment, appetite, food preferences, and food intake (Miwa et al., 2001, pp. 497, 500; Parvin et al., 2024, pp. 92–94). These challenges are not limited to complete anosmia. Individuals experiencing parosmia or other forms of olfactory distortion may also struggle to interpret food-related cues, since distorted smell or taste perception can make familiar foods feel unpleasant, unfamiliar, or difficult to identify (Ivona & Cortés Vega, 2021, pp. 2–4). Even when compensatory habits are adopted, many users continue to report food-related safety concerns, anxiety, and disruptions to food and cooking practices, suggesting that existing strategies do not fully address the practical consequences of smell loss (Lee et al., 2024, pp. 3642–3645; Fjaeldstad & Smith, 2022, pp. 1–2, 7).

Taken together, these findings show that olfactory impairment introduces a persistent challenge in everyday food safety practices. The problem is not only sensory, but also decisional: without a dependable way to independently assess food conditions, users may remain uncertain even when alternative cues are available. This highlights the need for more accessible and reliable approaches to support food-related decision-making when olfactory information cannot be depended upon.

2.1.2 Dairy Spoilage Mechanism and Observable Indicators

Among perishable food categories, dairy products provide a particularly relevant context for this study because odor often serves as one of the earliest signs of deterioration. In dairy products such as milk, yogurt, and cheese, spoilage may begin before obvious visible changes appear, making early assessment especially difficult for individuals who cannot rely on olfactory cues (Li et al., 2022, pp. 1, 4–5; Silcock et al., 2014, pp. 81–82). For this reason, dairy products offer a meaningful starting point for examining how food spoilage can be identified through alternative forms of assessment.

Dairy spoilage is a complex process driven by microbial activity and chemical degradation. As dairy products deteriorate, a range of changes may occur, including acidification, proteolysis, lipolysis, and changes in flavor, texture, and volatile compounds, depending on the specific microorganisms involved and the conditions of storage (Dairy Research Institute, 2021, pp. 2–6; Quigley et al., 2013, pp. 664–665). Because these processes do not follow a single uniform pathway, spoilage in dairy cannot be understood through one fixed indicator alone. Instead, different forms of deterioration may produce different observable or measurable signals.

Among these signals, several indicators have been widely discussed in existing research, including changes in volatile organic compounds, shifts in pH, and changes in physical properties such as turbidity or texture. Volatile organic compounds are generated as byproducts of microbial metabolism and are closely associated with odor perception. Experimental studies have identified alcohols, aldehydes, ketones, sulfur compounds, fatty acids, and esters as recurring signals of spoilage-related bacterial activity in milk (Decimo et al., 2018, pp. 593–594, 596–599). Because these compounds can reflect microbial activity during refrigerated storage, they are frequently treated as potential indicators for identifying deterioration before users rely solely on visible signs.

In addition to volatile compounds, pH is also commonly associated with dairy spoilage, particularly in cases involving acid-producing bacteria. However, spoilage does not always lead to a consistent decrease in pH, because different dairy products and spoilage organisms can involve different microbial pathways and environmental conditions (Quigley et al., 2013, pp. 664–665, 682; Dairy Spoilage, 2021, pp. 4, 9). Physical changes such as curdling, thickening, or increased turbidity may also occur during spoilage as a result of protein breakdown, acidification, or coagulation (Dairy Spoilage, 2021, pp. 3–6). While these changes can provide visible evidence of deterioration, they often appear later in the spoilage process and may require close inspection or direct handling of the product.

Taken together, these indicators show that dairy spoilage can be approached through multiple observable and measurable changes, but they do not offer the same type of information or the same level of practicality for everyday use. Some indicators are more closely tied to early spoilage, while others become visible only at later stages. This variation is important for the present study, because it helps define the range of possible detection directions before considering which approaches may be most appropriate for an accessible and user-centered design system.

2.1.3 Existing Detection Technologies

Existing research has explored a wide range of technologies for detecting food spoilage, including chemical sensing, biosensing, spectral analysis, and environmental monitoring systems. These methods rely on measurable indicators such as volatile organic compounds, pH variation, temperature, and microbial activity, and have been developed primarily in laboratory and industrial contexts, as well as in a smaller number of emerging consumer-oriented systems (Poghossian et al., 2019, pp. 1, 3–4, 8–9). While these technologies demonstrate that food spoilage can be assessed through multiple technical pathways, their suitability for everyday use varies considerably.

Many advanced detection methods remain confined to laboratory or industrial settings and require specialized equipment, controlled environments, or expert interpretation. Techniques such as electronic noses and ATP bioluminescence can provide rapid and sensitive detection, but they are often associated with high cost, complex operation, and limited accessibility for non-expert users in domestic contexts (Poghossian et al., 2019, pp. 3, 6, 8–9). As a result, although these technologies are technically effective, they are not easily translated into tools that can be readily used in everyday food-related decision-making.

Among alternative technologies, pH-based detection has also been explored as an indicator of food spoilage, particularly in controlled research settings. However, conventional spoilage-detection methods often require complex equipment, lengthy procedures, and trained personnel, while some existing pH indicator materials present limitations such as poor stability or toxicity concerns. Although food-compatible pH sensing strategies have been proposed, these often rely on specialized materials and controlled sample preparation, which may limit their practicality for routine consumer use (Wang et al., 2024, pp. 1–3, 9–12). In this sense, pH-based technologies may offer useful information, but they present challenges when considered in relation to affordability, safety, and ease of use.

Gas-based detection technologies, particularly those focusing on volatile compounds, suggest a direction that is more compatible with practical implementation. Jamdhade and Shingare (2024) compare several food spoilage detection methods and identify gas sensing as a relatively cost-effective and practical option for refrigerator-based spoilage monitoring. Their implementation also demonstrates that a metal oxide semiconductor gas sensor can be integrated with an Arduino-based system to collect real-time sensor readings and distinguish between fresh and spoiled food conditions in a refrigerator environment (Jamdhade & Shingare, 2024, pp. 1, 3–6). Compared with approaches that require direct food contact, expensive materials, or complex interpretation, this type of system indicates a more feasible basis for translation into everyday contexts.

Taken together, these existing technologies show that the challenge is not the absence of detectable spoilage signals, but the difficulty of translating technical detection methods into forms that are safe, affordable, accessible, and usable in daily life. This is particularly important for the present study, where the concern is not only whether spoilage can be measured, but how such measurement can be meaningfully integrated into an inclusive and user-centered design system.

2.2 Inclusive Design and the Knowledge Loop

This section introduces the conceptual and research framework that guides the study. The framework defines inclusive design as the conceptual perspective through which the research is positioned and then explains the knowledge loop as the framework used to structure how insights are translated into design development, evaluation, and iteration. Together, these two components provide the basis for examining how the study begins from the challenges faced by people with olfactory impairments in independently assessing food condition and exploring broader design implications.

2.2.1 Inclusive Design

In this study, inclusive design is used as the perspective for examining how everyday food safety decision-making often depends on smell, thereby insufficiently supporting people with olfactory impairments. As discussed in Section 2.1.1, everyday food-related decision-making often depends on reliable olfactory information, which means that individuals with olfactory impairments may be insufficiently supported in assessing food conditions independently. From this perspective, inclusive design is relevant not because it aims to address all forms of human difference at once, but because it begins by recognizing a specific unmet need and examines how responding to that need may also benefit a broader range of users.

As Treviranus (2018) describes, inclusive design begins by recognizing, respecting, and designing for human uniqueness and variability, while also considering inclusive processes and the broader systems in which design interventions take place (pp. 2–3).

Treviranus (2018) further describes an inclusive design approach through three main dimensions: recognizing and respecting human uniqueness and variability, using inclusive, open, and transparent processes that incorporate diverse perspectives into design, including those of people who cannot use or have difficulty using existing designs, and recognizing the complexity of the systems within which design takes place (pp. 2–3). Together, these dimensions help clarify how the present study is positioned. First, the project begins by recognizing a specific form of exclusion in everyday food-related decision-making, namely the assumption that all users can depend on smell to judge food condition. Second, the study does not treat users only as abstract recipients of a design outcome, but incorporates user participation through prototype testing and online survey methods in order to gather perspectives that can inform development. Third, the project is concerned not only with addressing one immediate use case, but with exploring how a design developed from a specific unmet need may have broader relevance across a wider range of users and situations.

A key definition that further supports this position is that "An inclusively designed product should only exclude the end-users who the product requirements exclude" (Clarkson et al., 2003, pp.95). In the present study, this principle is not used to define a fixed set of users who are already excluded by a finalized product. Instead, it is used to frame inclusive design as an iterative process of identifying and reducing unnecessary using demands as the design develops. In this sense, exclusion is not treated as fixed, but as something that can be progressively examined and reduced through repeated cycles of design, testing, and refinement.

Within this project, individuals with olfactory impairments therefore function as the starting point of the design rather than its final boundary. Their needs are used to reveal a specific form of exclusion, but the purpose of the study is not to produce a solution that is relevant only to this group. Instead, the research examines how a design developed from this starting point may also support a wider range of users, including those experiencing temporary smell loss, other forms of sensory variation, or uncertainty in assessing food conditions in everyday life. In this sense, inclusive design is used here as a way of moving from a specific unmet need toward broader usability and relevance.

2.2.2 The Knowledge Loop

Building on the inclusive design position outlined in Section 2.2.1, this study adopts the knowledge loop described by Keates and Clarkson (2003, pp.78-82) as a way of understanding design development as a cyclical rather than linear process. As shown in Figure 1(Keates & Clarkson, 2003, pp.79), the knowledge loop describes how user needs and experiences are translated into forms of knowledge that can be interpreted by designers, developed into products or services, returned to users for evaluation, and then reorganized into new representations that can inform subsequent refinement. In this way, the loop provides a structure for understanding how a design that begins from a specific unmet need may gradually expand its relevance through iteration.

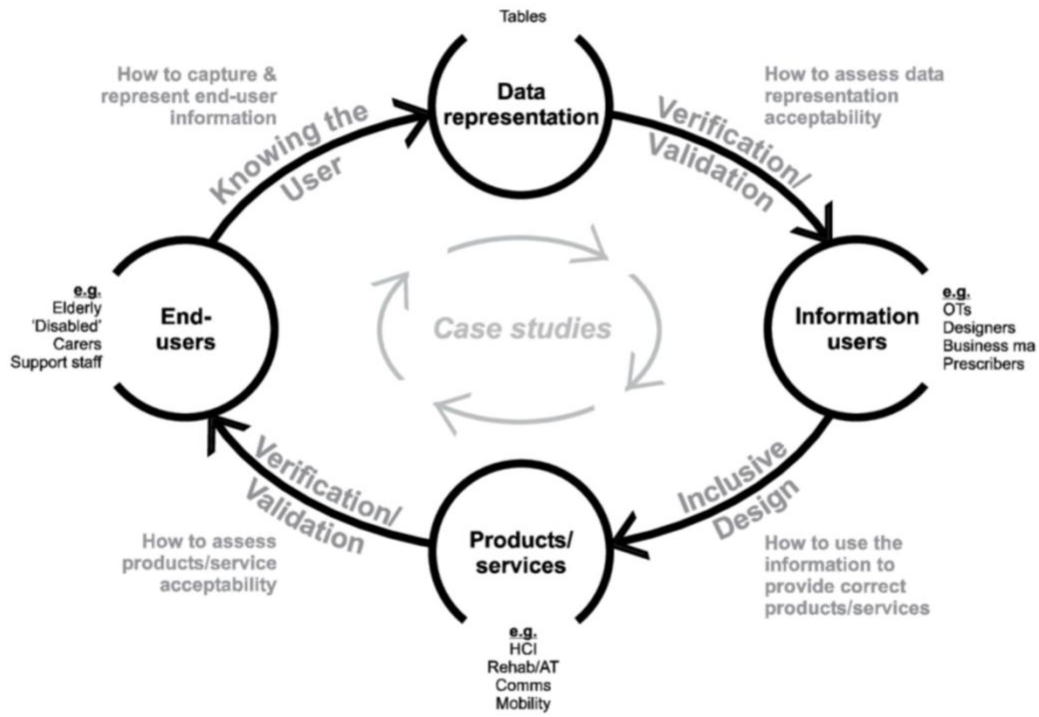

Figure 1 Knowledge Loop Design Framework

Note. Adapted from the Knowledge loop framework described in *Inclusive design: Design for the whole population* (pp.79), by S. Keates and P.J. Clarkson, 2003, Springer. The framework illustrates the iterative relationship. Between end users, data representation, information users, and products/services. https://doi.org/10.1007/978-1-4471-0001-0_6

In the present study, this process begins with the construction of an initial body of knowledge through literature and existing research related to olfactory impairment, dairy spoilage, food detection technologies, and inclusive interaction design. These insights are interpreted by the designer and translated into an initial prototype concept. The prototype is then returned to users through testing activities so that interaction difficulties, interpretive mismatches, and usability concerns can emerge as a new layer of feedback.

The study also extends beyond prototype testing to include an online survey. The survey was used to collect insights from a broader range of potential users regarding the form, function, and aesthetic qualities of preferred handheld kitchen appliances. These responses provided an additional layer of user-informed perspectives that could support reflection on the current prototype and inform directions for future refinement. Together, these two activities allow the study to gather both direct interaction-based feedback on the prototype and broader preference-based insights that may inform future design development.

These collected materials are then organized through analysis so that they can function as a new layer of data representation within the loop. Rather than remaining as raw feedback, they are interpreted and synthesized into structured insights and design guidance that can support future refinement. The present study concludes at this stage, after the initial prototype, user engagement, and analytical reorganization of findings. In this sense, the project does not complete a full second iteration, but establishes the basis from which a subsequent iteration can proceed.

2.3 Design Considerations for System Development

Before turning to prototype development, it is necessary to identify the main design considerations that emerge from the problem context, the technical conditions of dairy spoilage assessment, and the inclusive design position outlined above. These considerations do not yet determine the final form of the system. Instead, they establish the requirements that subsequent design decisions need to respond to in order to support usability, accessibility, and meaningful interaction.

In the present study, these considerations can be understood in two closely related dimensions. The first concerns the tangible aspects of the system, including physical interaction, grip, control, and sampling conditions. The second concerns the intangible aspects of the system, including interaction simplicity, cognitive load, and the communication of system states through feedback. Together, these dimensions provide the basis for translating earlier conceptual and technical insights into a design direction that can later be materialized as a prototype.

2.3.1 Tangible Design Considerations

The tangible dimension of the system concerns the physical conditions that shape how users handle, operate, and prepare the system for use. Because the proposed design involves both a handheld component and a sample-related component, physical interaction becomes a central design concern. In this context, design is not only a matter of external form, but also of how bodily movement, grip stability, input control, and material conditions influence the accessibility and reliability of the interaction process.

Ergonomics in Handheld Use

One important consideration is ergonomics in handheld use. Ergonomic guidelines indicate that handle dimensions significantly influence grip comfort, stability, and control. Research and industry guidance suggest that a handle diameter of approximately 30 to 50 mm can support a stable power grip, while a handle length exceeding 100 mm allows the device to be more fully supported by the palm, reducing localized pressure and improving handling (Canadian Centre for Occupational Health and Safety [CCOHS], 2023, “Diameter” and “Length” sections; Avient Corporation, n.d., pp. 6–8). Device weight is also a key factor affecting usability. Tools intended for one-handed operation should generally remain below 1.4 kg, and precision-oriented handheld tools are ideally much lighter, around 0.4 kg, in order to support control and reduce fatigue (CCOHS, 2023, “Weight of the tool” section). In addition, tool use should align with natural wrist and forearm positions, since improper alignment or awkward force direction may increase discomfort and reduce ease of use (CCOHS, 2023, “Handle shape” section). These considerations suggest that a handheld system for everyday food assessment should minimize unnecessary strain, support stable operation, and remain manageable for users with different levels of strength, coordination, and dexterity.

Grip, Form, and Tactile Guidance

Closely related to ergonomics is the role of grip, form, and tactile guidance. Industrial design guidance suggests that material behavior, grip mechanics, and weight distribution all affect how securely and intuitively a handheld device can be used (Avient Corporation, n.d., pp. 6–10). Different grip strategies, such as power grips and precision grips, offer different advantages, but also involve trade-offs between force and control (Avient Corporation, n.d., p. 6). This means that the physical form of a device should not rely on force-intensive interaction where stability can instead be supported through balanced structure, appropriate weight distribution, and tactilely informative surfaces. Surface treatments such as subtle texturing or soft-touch finishes may improve grip security, while form features such as shallow grooves or contoured surfaces can help guide hand positioning and reduce required grip force (Avient Corporation, n.d., pp. 7–9, 12–14). From an inclusive design perspective, these qualities are important not only for comfort, but also for reducing uncertainty during interaction and supporting users who may rely less on precise motor adjustment or constant visual monitoring.

Primary Control Input

Another key consideration concerns the design of the primary control input. Because the proposed system is expected to be operated through a limited number of physical actions, the button or trigger mechanism becomes especially important. Research on input accessibility shows that button size, placement, tactile distinguishability, and feedback all influence how accurately and confidently users can perform an action (Yu et al., 2022, pp. 6–7, 10–12; Federal Aviation Administration [FAA], 2003, pp. 6-34–6-35, 8-119–8-120). Larger buttons reduce the precision required for activation and may improve usability for a wider range of users, particularly older users (Yu et al., 2022, pp. 2, 6-7, 10-12). Placement also matters, since controls should be positioned so that they can be reached and activated during intended use without forcing users to reposition their grip (FAA, 2003, pp. 6-1–6-6, 14-35–14-42). In addition, buttons should provide clear and immediate feedback when activated, such as a mechanical click or another perceivable confirmation, so that users can understand whether an action has been successfully executed (FAA, 2003, pp.6-34, 6-52, 7-1 to 7-5). For users with reduced vision or different motor abilities, tactile markings and other non-visual cues are also important considerations, since they allow controls to be located and distinguished through touch rather than visual inspection alone (ISO, 2011, pp. 3–5; FAA, 2003, pp. 6-10–6-11).

Sample Preparation and Containment

In addition to the handheld component itself, the preparation and containment of the sample introduces another set of tangible requirements. As discussed in Sections 2.1.2 and 2.1.3, some spoilage indicators and detection directions require controlled sample conditions in order to support stable and repeatable measurement. Material selection and container structure therefore need to be considered not only in relation to food safety and contamination risk, but also in relation to the consistency of the assessment process. Food-grade polypropylene, for example, is widely recognized as suitable for food-related applications because it is considered non-toxic, chemically stable, and suitable for food-contact applications (IFT Mantova, 2024, "Characteristics and advantages of food grade polypropylene" section; "Is polypropylene food safe?" section). At the same time, research on reusable food packaging highlights that cleaning and reuse introduce additional hygiene and material-safety requirements. Reusable packages may accumulate dirt or contamination during circulation, while plastic food-contact materials can absorb components from food or cleaning agents, potentially leading to odour changes, unwanted chemical contamination, or migration during reuse. Therefore, reusability and contamination risk need to be carefully balanced in the design of sample-related components (Tenhunen-Lunkka et al., 2023, pp. 44, 48, 52–53; Geueke et al., 2023, pp. 2, 13). The structure of the container must also support stable and repeatable measurement conditions. Technical guidance on headspace gas sampling indicates that measurement accuracy can be affected by the available headspace volume, package rigidity, and analyzer design. In Bridge Analyzers' MAP headspace gas testing guidance, 25–50 mL of headspace gas is described as adequate for standard measurements in soft packages, while rigid containers may require a larger starting headspace volume to deliver an equivalent measurable gas sample (Bridge Analyzers, 2019, "Sample Volume Considerations" and "Gas Sampling Considerations for Rigid Containers" sections). Similarly, the amount of sample relative to container volume affects the release and detection of gases. Technical guidance on headspace sampling recommends that the sample occupy approximately 10–50% of the vial volume, in order to avoid interfering with the release of volatile substances and to support gas-liquid equilibrium during analysis ("Basics of Headspace Sampling," 2024, "Usage Method" section). These findings indicate that sample handling is not merely an auxiliary step, but a physical part of the interaction system that must be designed with the same degree of care as the handheld device itself.

Taken together, these considerations show that the tangible design of the system must respond simultaneously to physical usability, perceptual accessibility, and measurement conditions. Ergonomics, grip, control, material safety, and sampling structure are therefore treated in this study not as isolated technical details, but as interconnected physical requirements that shape how the system can be meaningfully and inclusively used.

2.3.2 Intangible Design Considerations

In addition to the system's tangible requirements, the proposed design also depends on a set of intangible considerations related to how interaction is structured, how information is communicated, and how users interpret system states during use. In the context of this study, these concerns are especially important because the system is not intended to operate as a purely technical detector, but as an interaction-based support for food-related decision-making. This means that usability depends not only on physical handling, but also on whether users can understand what the system is doing, what it is asking them to do, and how to interpret its feedback in a clear and confident way.

Interface Simplicity and Cognitive Load

One key consideration is interface simplicity in relation to users' cognitive load. Research on cognitive ergonomics and interface design suggests that users are not equipped with greater cognitive capacity simply because a system offers more functionality or complexity. As systems become increasingly complex, interaction flows and excessive features can exceed users' available cognitive resources, making simplicity and task relevance important considerations in interface design (van der Veer, 2008, pp. 2618–2621). From this perspective, simplifying functions and reducing unnecessary features are not merely aesthetic preferences, but essential strategies for improving usability. In a system intended to support everyday food assessment, interaction should therefore remain as clear and manageable as possible, minimizing the number of steps, choices, and interpretive burdens required from the user.

Visual Guidance and Information Organization

Closely related to this is the role of visual guidance and the organization of information. Research on age-friendly interface design suggests that simplified navigation, readable interfaces, enlarged touch targets, and improved feedback can enhance usability and reduce barriers for older users (Amouzadeh et al., 2025, pp. 1–3). At the same time, relying solely on written instructions may introduce barriers due to language differences, literacy levels, or the pressure of having to process information quickly in the middle of an everyday task. Research on pictogram design suggests that visual symbols can support accessibility when they are designed to be intuitive, context-sensitive, and culturally comprehensible, reducing reliance on written language and supporting broader user groups (Bühler et al., 2022, pp. 1–4, 10–11). These findings indicate that intangible design considerations are not limited to what information is presented, but also include how that information is structured so that users can recognize and interpret it without unnecessary effort.

Multimodal Feedback

Another major consideration is how the system communicates status and outcome through feedback. As users interact with the system, they depend on feedback to understand whether an action has been registered, what stage of the process has been reached, and whether the system is communicating a safe, cautionary, or critical condition. Research on multimodal cueing suggests that presenting information through multiple sensory channels can support detection and interpretation of system states, especially in complex or high-load environments. When feedback is delivered through more than one modality, such as visual, auditory, and tactile cues, information can be communicated redundantly, increasing the likelihood that users perceive the message when one sensory channel is limited or overloaded (Baldwin et al., 2012, pp. 1431–1434). This is particularly important in situations where one sensory channel may be limited, ensuring that critical information remains accessible through alternative means.

Multimodal Feedback-Visual Feedback

Within this multimodal framework, visual feedback plays an important role in communicating urgency and system status. Research suggests that color carries strong associations with perceived hazard levels, with red typically conveying the highest level of hazard, while colors such as green and blue are generally associated with lower perceived hazard in comparison (Braun & Silver, 1995, pp. 831–834). Temporal variation also affects interpretation, as faster flash rates and multiple-flash modes are generally associated with higher perceived hazard or urgency, although overly intense flashing may also introduce annoyance or reduced usefulness (Chan & Ng, 2009, pp. 346–350). These findings suggest that visual feedback should not be treated as a neutral decorative element, but as a structured communication layer capable of signaling differences in urgency and status.

Multimodal Feedback-Auditory Feedback

Auditory feedback complements visual communication by conveying urgency through temporal rhythm, repetition rate, and other acoustic qualities such as pitch. Research on warning sounds suggests that faster rates and higher pitches are generally associated with greater perceived urgency, while slower temporal patterns tend to communicate less urgent conditions. In experiments using reaction time as an objective measure, shorter intervals between sound pulses were associated with faster responses, indicating that temporal density can affect how quickly users recognize and respond to system output (Suied et al., 2008, pp. 201–205, 210–211). In this sense, auditory feedback can do more than simply confirm that a system is active. It can also communicate qualitative differences in system state, provided that the patterns remain interpretable and consistent.

Multimodal Feedback-Tactile/Vibrative Feedback

Tactile feedback similarly contributes to the communication of system status through variation in vibration pulse rate and interpulse interval. Research on tactile alerts suggests that faster pulse rates and shorter intervals are generally associated with higher perceived urgency, while slower pulse rates and longer intervals indicate lower urgency (Pratt et al., 2012, pp. 1303–1306). This suggests that tactile output can function not only as a basic confirmation mechanism, but also as a meaningful carrier of graded information. For users who may rely less on visual or auditory channels in a given context, tactile feedback can therefore serve as an important part of an accessible communication system.

Taken together, these considerations show that the intangible dimension of the system must support clear interpretation, reduced cognitive burden, and accessible communication of system states. Simplicity, visual guidance, and multimodal feedback are therefore treated in this study not as secondary interface details, but as central design requirements that shape how the system can become understandable, trustworthy, and meaningfully usable across a diverse range of users.

3.0 Research Methods

Building on the conceptual and methodological position outlined in Chapter 2, this chapter describes the research methods used to carry the study from initial design development into user engagement and analytical interpretation. In relation to the knowledge loop discussed in Section 2.2.2, this chapter focuses on how the project moves from an initial prototype into the collection and organization of user-informed insights. More specifically, it explains how data were gathered through prototype testing and an online survey, and how the resulting materials were analyzed and reorganized into structured findings that could inform subsequent design refinement.

The chapter is divided into two main parts. Section 3.1 outlines the data collection methods used in the study, including prototype testing and an online survey. Section 3.2 then explains how the materials generated through these activities were processed and interpreted through qualitative analysis. Together, these methods provide the basis for understanding how the study translated user engagement into a new layer of data representation, while also clarifying the point at which the present research concludes within the broader iterative process.

3.1 Data Collection Methods

This section outlines the data collection methods used in the study. In relation to the iterative process described in Section 2.2.2, these methods were designed to return the initial prototype to users and to gather a broader range of user-informed perspectives that could support subsequent analysis and future refinement. The study combines two complementary forms of data collection: prototype testing and an online survey. Together, these methods allow the research to capture both direct interaction-based responses to the proposed system and broader perspectives on handheld kitchen tools and everyday use.

Both methods were conducted under OCAD Research Ethics Board approval (*Appendix M: REB Approval Letter*) and were intended to support the study’s focus on interaction, usability, and user interpretation rather than technical validation. The first method, prototype testing, was used to examine how participants understood, operated, and responded to the proposed system within a structured everyday scenario. The second method, the online survey, was used to extend the range of user input beyond the immediate testing context and to gather additional insights from a wider range of potential users. The following two subsections describe these methods in greater detail.

3.1.1 User Testing

User testing was conducted to examine how participants understood, operated, and interpreted the proposed system within a structured everyday scenario. In relation to the iterative logic described in Section 2.2.2, this method functioned as the stage at which an initial prototype concept was returned to users so that interaction difficulties, interpretive mismatches, and usability concerns could emerge through direct engagement. All user-involved activities in this study were conducted under OCAD Research Ethics Board approval prior to data collection.

A total of nine participants took part in the in-person user testing sessions. Participants were recruited primarily through the university context with posters, with a smaller number recruited through personal networking channels with posters. As a result, the testing group was concentrated largely within a university student population. While this participant group did not represent the full range of potential users relevant to the study, it provided a practical starting point for examining whether the proposed interaction process could be understood and carried out in practice.

Each testing session was structured around a kitchen-based everyday use scenario. Participants were placed in a domestic cooking context in which they needed to decide whether previously opened milk was still suitable for use before adding it to a dish. The scenario was intentionally situated in the kitchen because the proposed system is intended to support food-related decision-making within ordinary domestic routines rather than in a laboratory or industrial setting. Using a kitchen context therefore helped place the interaction within a familiar and meaningful situation, allowing participants to approach the testing process as part of an ongoing everyday activity rather than as an abstract technical task. Based on this scenario, participants were guided through several structured tasks that reflected the intended interaction flow of the proposed system. The full testing procedure is provided in *Appendix B: Testing Protocol.*

While the task sequence provided a consistent structure across participants, no explicit instructions were given on how to perform each step. Participants were informed of the task goals, but were allowed to interpret the interaction independently. This approach made it possible to observe how users made sense of physical cues, interface elements, and system feedback on their own, and to identify points of uncertainty or mismatch between design intention and actual user behavior. For this reason, the task-based testing was combined with a semi-structured interview format, allowing follow-up questions to be asked when hesitation, confusion, or unexpected behavior emerged during the session. The interview prompts and six testing tasks are included in *Appendix B: Testing Protocol*.

Before participating, all individuals reviewed and signed *Appendix A: In-Person Consent Form*, including consent for audio recording during the session. To support accessibility across different linguistic backgrounds, the testing materials were prepared in English, Chinese, and Japanese. During the sessions, participants were also given a supporting reference sheet to assist them in interpreting system states during interaction. This material is included in *Appendix C: Device State Reference Sheet*. The specific design of the prototype and the system it supported are discussed in Chapter 4.

The purpose of user testing in this study was not to evaluate technical detection accuracy, but to examine how participants perceived and interacted with the proposed system as an inclusive interaction concept. More specifically, the sessions were intended to reveal how users responded to the interaction flow, where uncertainty emerged, how system feedback was interpreted, and what aspects of the process created difficulty or hesitation. These observations formed one of the main sources of user-informed data later analyzed in the study.

3.1.2 Survey

In addition to in-person user testing, the study incorporated an online survey in order to extend the range of user input beyond the immediate testing context. As noted in Section 2.2.2, the in-person testing group was limited in range because participants were recruited mainly through the university context and a smaller number of personal networking channels. The survey was therefore introduced as a complementary method for gathering broader perspectives from a wider range of potential users. Rather than focusing on direct interaction with the prototype, this method was intended to collect user preferences and reflections that could inform future refinement of the system.

The survey was distributed across three online social media platforms: Reddit, Rednote, and SNS. These platforms were used in English, Chinese, and Japanese respectively, reflecting the three languages in which the researcher was able to prepare materials and communicate with participants. This multilingual distribution strategy was adopted in order to broaden the range of users who could contribute insights within the practical scope of the study. By extending recruitment beyond one linguistic or social context, the survey aimed to gather a more diverse set of perspectives than could be obtained through in-person testing alone.

The survey focused on user preferences regarding handheld kitchen tools, including their functional, formal, and aesthetic qualities. Participants were asked to upload an image of a handheld kitchen device they liked and to provide a short-written explanation of why they preferred it. In this way, the survey was designed to capture not only visual references related to form, but also users' own interpretations of the functional, formal, and aesthetic qualities they found meaningful or appealing. The survey interface and question format are provided in *Appendix D: Survey Material*.

Participation in the survey was voluntary. Before submitting a response, participants were presented with online consent information explaining the purpose of the survey and the conditions of participation. Only responses from participants who agreed to these terms were collected. The consent material is included in *Appendix E: Online Consent Material*.

The purpose of the online survey was not to evaluate the proposed system directly, but to broaden the study's understanding of how potential users perceive handheld tools in everyday kitchen contexts. By collecting image-based references together with short written explanations, the survey provided a wider range of user-informed insights that could complement the more interaction-specific findings generated through in-person testing. The full set of collected survey responses is compiled in *Appendix K: Online Forms Responses*.

3.2 Data Analysis

The materials collected through user testing and the online survey were analyzed in order to transform raw feedback into a structured and interpretable body of findings. While this stage corresponds to the point at which collected feedback is reorganized into a new layer of data representation, the purpose of analysis in this study was not to restate user responses in raw form, but to identify recurring concerns, clarify patterns across participants, and organize the results in a way that could inform later design refinement. In this sense, the analytical process functioned as a means of synthesizing user-informed materials into structured insights and potential design guidance.

The analysis of the in-person testing materials was informed by thematic analysis, a qualitative method used to identify, analyze, and report patterns or themes across a data set (Braun & Clarke, 2006, pp. 79–80). All testing sessions were audio-recorded with participant consent and subsequently transcribed, allowing spoken comments, observed behaviours, and moments of hesitation or uncertainty to be examined in detail. This process supported the first stage of thematic analysis, in which researchers become familiar with the data through transcription, reading, re-reading, and noting initial ideas (Braun & Clarke, 2006, pp. 87–88). The transcribed materials were then reviewed across participants to generate initial codes and identify repeated patterns of concern, interpretation, and interaction difficulty, following Braun and Clarke's description of coding as the systematic organization of meaningful features within the data (Braun & Clarke, 2006, pp. 88–89). This made it possible to move from individual testing sessions to cross-participant comparison, allowing recurring issues and interpretive patterns to emerge more clearly.

At the same time, thematic analysis is inherently interpretive and depends on the researcher's judgment in coding and categorizing data. To reduce ambiguity within the scope of this project, the analysis was organized through a defined coding structure. Transcribed testing data were first grouped into three primary categories based on the main locus of feedback: device-related interaction, app-related interaction, and other observations that did not fit neatly into either of the first two groups. These materials were then further organized into six broader thematic groupings reflecting different aspects of user experience and interaction. The list of themes, definitions, and thematic groupings is provided in *Appendix F: Coding*.

Following this structure, participant feedback was documented and organized in detail under the three primary categories. Device-related feedback was compiled in *Appendix G: In-Person Feedbacks_DEVICE*, app-related feedback was compiled in *Appendix H: In-Person Feedbacks_APP*, and additional observations were compiled in *Appendix I: In-Person Feedbacks_OTHER*. These appendices include participant comments, relevant actions or behavioral observations, and brief interpretive notes that helped clarify how each instance of feedback related to the coding structure. This organization allowed the analysis to preserve the specificity of individual responses while also preparing the material for cross-participant comparison.

To support synthesis across participants, the materials from Appendices G, H, and I were then consolidated into *Appendix J: Feedback Summary*. This summary table records recurring feedback patterns by noting how many of the nine participants expressed similar concerns, preferences, or difficulties within each theme when such counting was meaningful, while also retaining noteworthy observations that could not be reduced to simple frequency counts. In this way, the summary did not function merely as a count of repeated comments, but as a bridge between detailed coded materials and the more interpretive design insights developed later in section 6.1.1 and 6.2.1.

The online survey generated a different form of material and was therefore organized somewhat differently. Rather than interaction-based observations, the survey produced image-based references and short written explanations of user preferences regarding handheld kitchen tools. These responses were reviewed and organized into a structured table that included uploaded images, participant explanations, and three broad descriptive categories: function, form, and aesthetics. The compiled survey responses are provided in *Appendix K: Online Forms Responses*. Where necessary, submitted materials were reviewed and anonymized to remove or obscure identifiable personal information before analysis in order to maintain participant confidentiality.

Taken together, the analysis of testing transcripts and survey responses allowed the study to move beyond raw feedback and toward a more structured representation of user-informed insights. These analytical outputs did not yet constitute a second design iteration, but they established the basis from which subsequent refinement could proceed. In this sense, analysis in the present study served as the stage that prepared the transition from user engagement to future design development by identifying themes, summarizing recurring issues, and organizing feedback into a form that could support later design decisions.

4.0 Prototype Development

Building on the conceptual foundations established in Chapter 2, this chapter focuses on the development of the prototype used in the study. At this stage, the discussion moves from the earlier consideration of spoilage indicators, detection technologies, inclusive design, and interaction requirements into the translation of those insights into a tangible system. Because the prototype is not presented as a single isolated object, but as the outcome of multiple interconnected design decisions and development processes, this chapter first outlines the key decisions that shaped the overall direction of the system before turning to the practical development of its individual components.

Figure 2 presents an exploded view of the prototype as an overview of the system developed in this study. Rather than functioning only as a visual summary, this figure also provides a way of locating how different parts of the prototype relate to the design decisions and development stages discussed in the following sections. In this way, the figure supports the chapter by linking the overall system view to the more specific decisions and making processes described later.

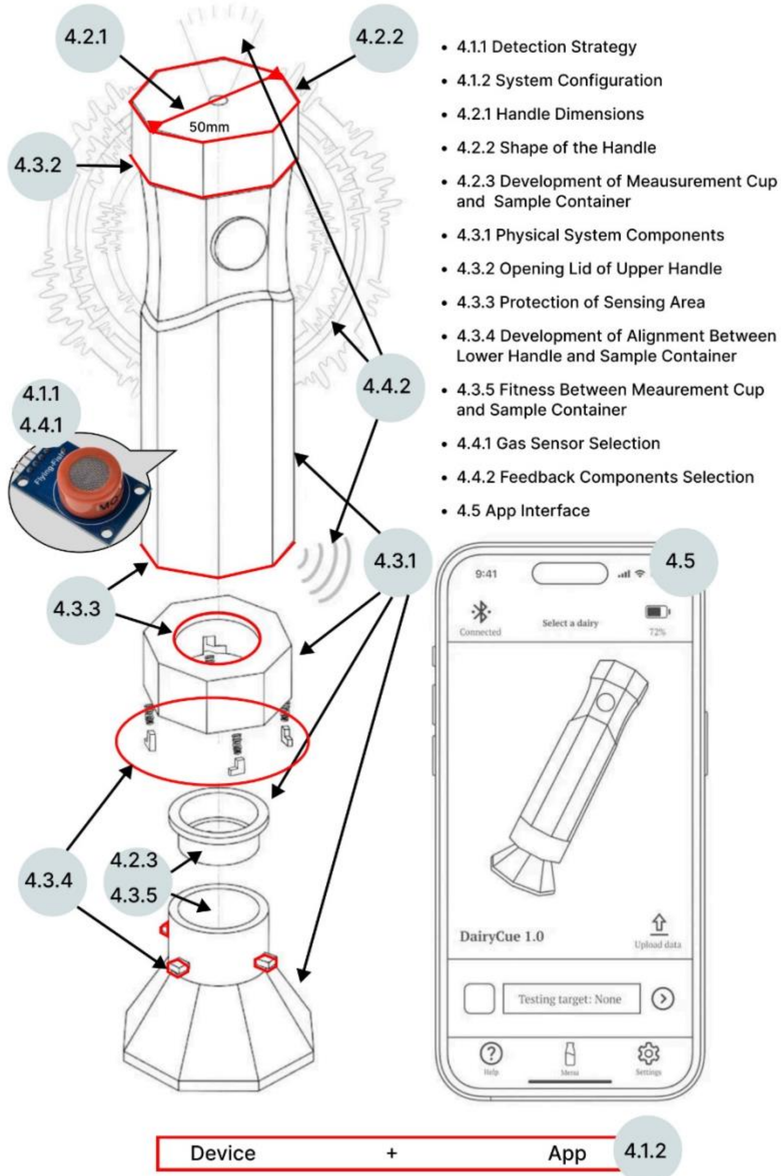

Figure 2 Exploded View of Prototype

The chapter is therefore organized in two parts. Section 4.1 outlines the two main design decisions that guided prototype development, including the selection of a detection strategy and the overall configuration of the system. Sections 4.2 to 4.4 then describe how these decisions were translated into the development of the prototype through form exploration, physical construction, functional simulation, and interface design. The chapter concludes by bringing these components together as a unified prototype system prepared for user testing.

4.1 Design Decisions Guiding Prototype Development

Before turning to the making of the prototype itself, it is necessary to clarify the main design decisions that shaped its overall direction. These decisions did not emerge independently from fabrication, but were derived from the earlier discussion of spoilage indicators, detection technologies, inclusive design, and the tangible and intangible considerations identified in Chapter 2. In this sense, prototype development in the present study is understood not simply as a process of producing form, but as a process of translating earlier conceptual and technical insights into a coherent system direction.

The following two subsections address the two foundational decisions that guided later development. Section 4.1.1 explains the selection of the detection strategy, and Section 4.1.2 discusses the overall configuration of the system as a combined device-and-application structure. Together, these decisions establish the basis for the more specific development processes described in Sections 4.2 to 4.4.

4.1.1 Detection Strategy

The first design decision guiding prototype development concerned the selection of an appropriate detection strategy. As discussed in Sections 2.1.2 and 2.1.3, dairy spoilage can be understood through multiple observable and measurable indicators, including volatile organic compounds, pH variation, microbial activity, and physical changes such as flavour, odour, coagulation, turbidity, or texture. While some studies focus specifically on milk, these indicators are relevant to this study because milk was used as the primary testing context within a broader dairy-focused design problem. VOCs have been studied as potential chemical spoilage indexes for psychrotrophic bacterial activity in milk, while broader dairy spoilage literature identifies microbial growth, acidification, enzymatic degradation, proteolysis, lipolysis, off-odours, and texture changes as important spoilage mechanisms (Decimo et al., 2018, pp. 593–595; Quigley et al., 2013, pp. 664–665; Dairy Research Institute, 2021, pp. 1–6). However, these indicators do not provide the same kind of information, nor do they offer the same level of suitability for a system intended to support everyday food-related decision-making. The selection of a detection strategy in this study therefore required not only technical relevance, but also compatibility with accessibility, affordability, and interaction-oriented design.

Among these possible directions, volatile organic compounds were identified as the most appropriate point of departure. As noted earlier, volatile compounds are generated through microbial activity and are closely associated with odor perception and flavor change. Existing studies have identified VOCs as potential spoilage or freshness markers, including compounds such as alcohols, ketones, aldehydes, sulfur compounds, fatty acids, and esters (Decimo et al., 2018, pp. 593–595; Li et al., 2022, pp. 1–2, 4–7). This relationship is especially significant in the context of the present study, because the problem being addressed is directly connected to the absence of reliable olfactory information. In this sense, volatile-compound detection provides a way of accessing information that is conceptually aligned with the role that smell normally plays in everyday food assessment. Rather than introducing a completely unrelated measurement logic, it allows the system to work with a form of information that corresponds more closely to the sensory cue that users would otherwise depend upon.

By contrast, the alternative indicators considered in Chapter 2 presented more substantial limitations when viewed from a design perspective. pH-based approaches are relevant to spoilage, but their usefulness is constrained by inconsistency across different dairy spoilage scenarios, since spoilage may involve either acid production or alkaline compounds depending on microbial activity and food context (Quigley et al., 2013, pp. 664–665; Wang et al., 2024, pp. 1–2). Although newer food-safe pH sensing materials have been proposed, they often rely on specialized sensing structures and supporting materials, which may complicate their translation into a low-cost everyday-use device (Wang et al., 2024, pp. 1–6). Physical indicators such as turbidity, curdling, or texture change also remain meaningful, but they generally emerge as visible or material changes after microbial or enzymatic activity has already affected the product, and therefore depend more heavily on user inspection and interpretation (Dairy Research

Institute, 2021, pp. 2–6). More advanced laboratory-based systems offer high sensitivity, but they are less compatible with the present study because they introduce challenges of cost, complexity, equipment requirements, trained operation, and limited accessibility in domestic contexts (Poghossian et al., 2019, pp. 1–3). As a result, the decision could not be made on the basis of technical precision alone, but needed to consider how a given approach could be translated into an accessible and user-centered system.

Within this context, gas-based detection using volatile-compound sensing emerged as the most suitable direction for the study. Compared with the alternative indicators considered above, it offered a stronger balance between scientific relevance, practical feasibility, and compatibility with the goals of the project. In particular, Jamdhade and Shingare's comparison of food spoilage detection methods identifies gas sensing as a relatively cost-effective, real-time, and refrigerator-compatible approach. Their implementation further shows that a metal oxide semiconductor gas sensor can be integrated with an Arduino-based system to support prototype-level spoilage monitoring (Jamdhade & Shingare, 2024, pp. 1, 3–6). This made gas-based sensing more compatible with the study's aim of developing a supportive interaction system rather than a laboratory-grade testing device.

The decision-making process underlying this selection is summarized in Table 1, which compares the strengths and limitations of the main detection directions considered in the study. Taken together, this decision established the technical direction that made later prototype development possible. It did not determine the final form of the system on its own, but it set the conditions within which later design decisions had to operate. Once the study moved toward a detection strategy that required contextual interpretation and accessible communication, the overall configuration of the system became the next major design decision.

Detection Method	Strength	Limitation	Suitability to this project
VOC (Gas)	Directly linked to odor; early detection	Requires calibration	Selected
pH	Related to microbial activity and freshness change	Inconsistent; food safety and cost issue	N/A
Turbidity	Visible or physical evidence of deterioration	Late-stage; Subjective	N/A
Lab based detection	High sensitivity and technical accuracy	Expensive; Complex	N/A

Table 1 Decision process for selecting detection strategy

4.1.2 System Configuration

The second major design decision concerned the overall configuration of the system. Once a volatile-compound-based detection direction had been identified, the next question was how that detection process should be organized into a usable interaction system. In the present study, this decision was shaped by two related issues discussed earlier in Chapter 2. First, dairy spoilage does not follow a single uniform pattern across different product types or storage conditions, and spoilage-related VOCs may vary depending on microbial activity and context (Quigley et al., 2013, pp. 664–665; Decimo et al., 2018, pp. 593–595). Second, the system needed to remain understandable and manageable within an everyday interaction context. Cognitive ergonomics research suggests that increasingly complex systems do not give users additional cognitive capacity, and that design should account for users' goals, activities, and contexts of use (van der Veer, 2008, pp. 2618–2621). For this reason, the project did not develop as a single self-contained device, but instead moved toward a combined configuration consisting of a physical device and a supporting application.

A major reason for this decision was the contextual variability of dairy spoilage. As discussed in Sections 2.1.2 and 2.1.3, dairy products can undergo spoilage through different microbial and biochemical processes, and spoilage-related signals may vary depending on product type, microorganisms involved, storage conditions, and product composition. Broader dairy spoilage literature identifies different organisms and mechanisms across products such as yogurt, cheese, cream, butter, and other dairy products, including acidification, proteolysis, lipolysis, gas production, off-odours, coagulation, and texture changes (Quigley et al., 2013, pp. 664–665; Dairy Research Institute, 2021, pp. 2–6; Decimo et al., 2018, pp. 593–595). This meant that the system could not reasonably rely on a single fixed threshold or one undifferentiated detection logic for all cases. Some form of contextual input was therefore necessary so that the system could distinguish what type of dairy product was being assessed before the detection result was interpreted.

At the same time, placing this contextual input directly onto the physical device would have introduced additional interaction complexity. As discussed in Section 2.3.2, systems with complex interaction flows, excessive functions, or dense information structures can increase users' cognitive load and make operation more difficult in everyday contexts. Cognitive ergonomics research notes that increasingly complex systems do not give users additional cognitive capacity, while age-friendly interface research emphasizes simplified navigation, readable interfaces, enlarged touch targets, and error-tolerant interaction as ways to reduce barriers (van der Veer, 2008, pp. 2618–2621; Amouzadeh et al., 2025, pp. 1–3). If the physical device were responsible not only for detection, but also for selecting product categories and managing more detailed contextual settings, the interaction process would become more cumbersome and harder to interpret. This would conflict with the broader aim of keeping the system accessible and manageable as an everyday tool.

For this reason, the study moved toward a distributed system structure in which the application and the physical device perform different but complementary roles. The supporting application provides the space for contextual input and more explicit information organization, allowing users to specify the type of dairy product being tested before detection begins. The physical device, by contrast, serves as the primary point of embodied interaction, supporting the testing action itself and the communication of immediate system states. This division of roles made it possible to reduce the complexity of the physical interaction while still allowing the system to operate with a necessary degree of contextual specificity.

This configuration was also consistent with the study's concern for accessible communication. As discussed in Section 2.3.2, multimodal feedback can improve the perception and interpretation of system states by distributing information across visual, auditory, and tactile channels, especially when one sensory channel may be limited, overloaded, or less available (Baldwin et al., 2012, pp. 1431–1434; Yun & Yang, 2020, pp. 1–5; Ma et al., 2022, pp. 1–4). A combined device-and-application structure therefore offered an additional advantage: it allowed the system to distribute communication across physical and digital layers. Immediate feedback could be delivered through the device during use, while more explicit or contextualized information could be supported through the application. In this sense, the system configuration was not only a technical arrangement, but also a communication strategy.

Taken together, these considerations led to the decision to develop the prototype as a combined device-and-application system rather than as a single stand-alone object. This decision established the organizational logic that later development needed to follow. Once the relationship between contextual input, physical interaction, and layered feedback had been defined in this way, the next stage of development concerned how these requirements would begin to take physical and operational form through prototype exploration.

4.2 Form Exploration

Following the two design decisions outlined in Section 4.1, the next stage of development focused on form exploration. At this stage, the objective was not yet to resolve all structural or technical details, but to investigate how the prototype could be physically held, oriented, and positioned during use. In other words, the form exploration stage examined how earlier design considerations related to ergonomics, grip stability, tactile guidance, and sample handling could begin to take shape in a workable physical direction.

4.2.1 Handle Dimensions

The exploration began with handle dimensions. As discussed earlier in Section 2.3.1, ergonomic guidance from CCOHS suggests that a handle diameter between approximately 30 and 50 mm can support stable grip and comfortable handling for tools intended for a power grip (CCOHS, 2023, "Design of Tool Handles" section). However, the most appropriate dimension within this range was not immediately clear in practice. Avient ergonomic grip design guide emphasizes that handheld grip design should be developed in relation to the specific use case, user characteristics, grip architecture, and pre-production validation (Avient Corporation, n.d., pp. 1–7, 11). To explore this further, a series of informal grip comparisons was conducted using commonly available aluminum cans with different diameters, as shown in Figure 3. These objects were selected because their standardized cylindrical forms provided a simple and familiar basis for comparing grip comfort and perceived stability. Through this process, a diameter of approximately 50 mm emerged as the most stable and comfortable reference point for subsequent form development.

Figure 3 Aluminum Cans for Diameter and Grip Exploration

4.2.2 Shape of the Handle

Building on this initial ergonomic reference, the exploration continued through an examination of existing handheld devices designed for enclosed food-related operations. In particular, a commercial vacuum-sealing device was used as an early point of reference, as shown in Figure 4. This type of device provides a useful interaction model because it operates through a compact handheld unit positioned over a sealed container, allowing the user to apply downward force onto an enclosed internal environment. Based on this reference, early sketches were developed to explore how measurement placement, device orientation, and hand positioning might be organized within a coherent form, as shown in Figure 5.

Figure 4 Zwilling Vacuum-Sealing Device

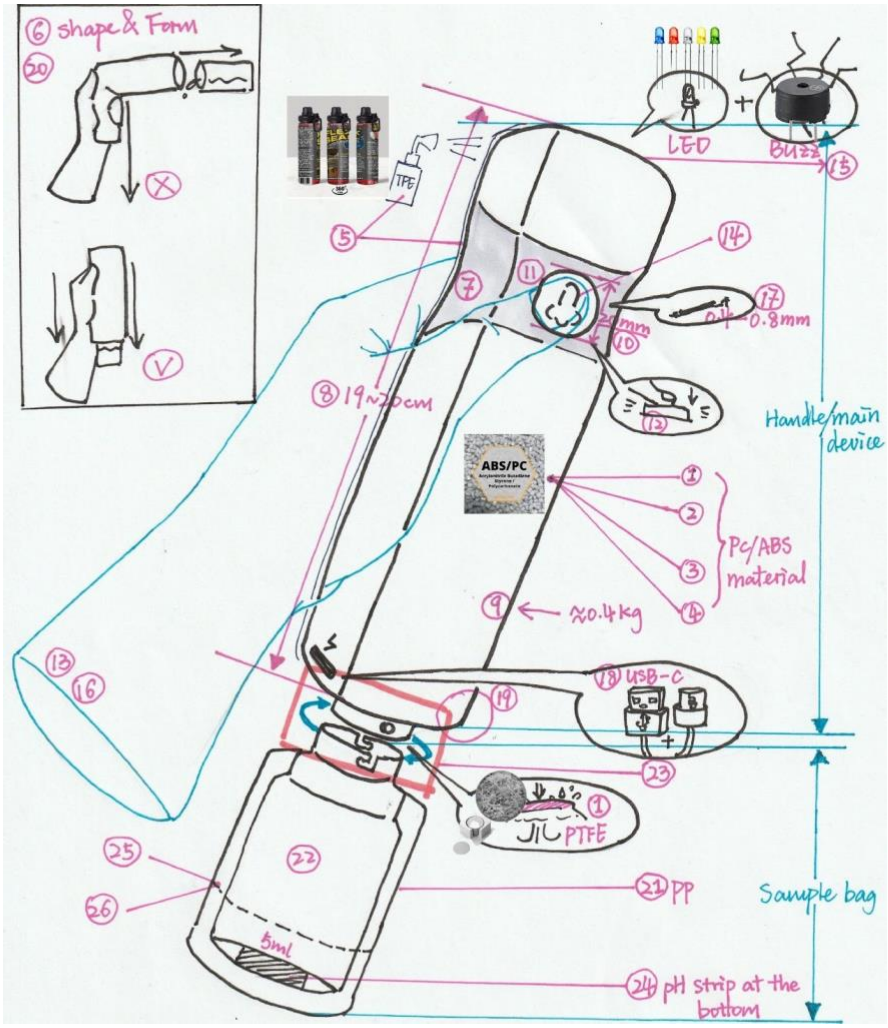

Figure 5 Early Sketch

At the same time, the reference model also revealed important limitations. While the rounded rectangular geometry of the original device offered a smooth and safe surface for repeated everyday handling, it also provided relatively limited resistance to rotation during operation. This became a concern because the proposed interaction required stable downward force on a flat surface, where even slight misalignment could reduce control. In response, the form was refined through iterative exploration. Rather than maintaining a rounded profile, the design moved toward a faceted geometry with softened edges, resulting in an octagonal-rounded form, as shown in Figure 6. This adjustment emerged through hands-on testing rather than direct imitation of an existing reference. The introduction of subtle flat surfaces helped increase rotational resistance during use while preserving the comfort and safety associated with rounded edges. In this way, the form began to balance stability and comfort more effectively.

Figure 6 Octagonal Paper Model

To further evaluate the emerging form, a series of low-fidelity paper models was produced, as shown in Figure 7. These models allowed rapid testing of scale, grip comfort, and overall proportions. They also made it possible to assess how the device might be held in one hand, how force would be applied during use, and how the spatial relationship between the handheld component and the sampling area might affect usability. Because these models were quick to make and easy to revise, they provided an efficient way of testing form-related assumptions before moving into more resolved fabrication.

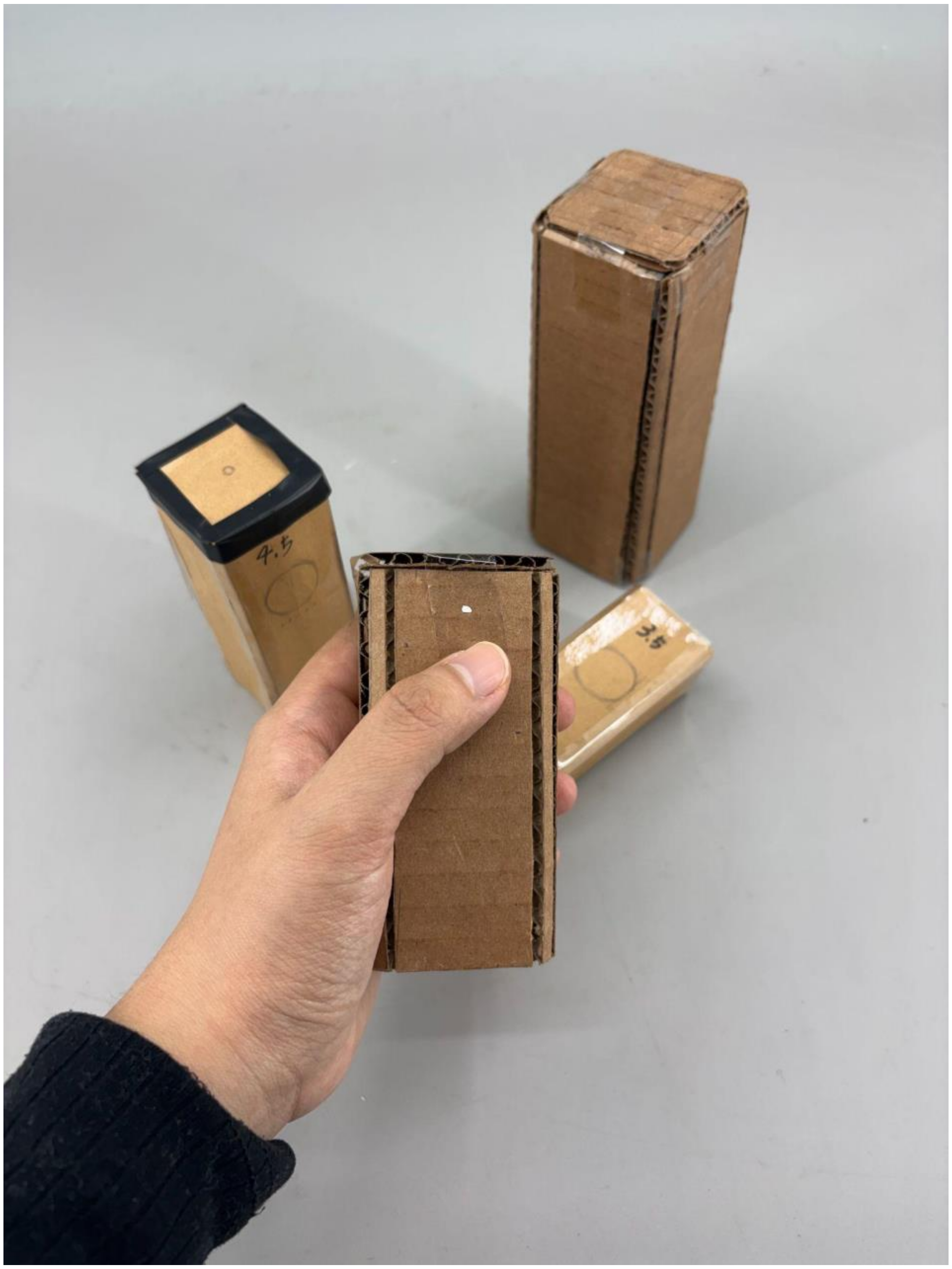

Figure 7 Paper Models for Testing of Scale, Grip Comfort, and Overall Proportions

4.2.3 Development of Measurement Cup and Sample Container (Cup)

In addition to overall form and grip, this early stage also supported exploration of sample handling and measurement. Based on the sampling considerations discussed in Section 2.3.1, technical guidance on headspace sampling recommends that the sample occupy approximately 10–50% of the vial volume in order to support volatile release and gas-liquid equilibrium during analysis (“Basics of Headspace Sampling,” 2024, “Usage Method” section). In relation to the scale of the prototype container, this guidance was translated into an approximate working sample range of 3 to 5 mL. This introduced a practical question: how could users consistently collect an appropriate amount of sample during everyday use? An initial idea was to use a separate measurement cup, but early exploration showed that this component lacked a clear formal relationship with the rest of the system and appeared too isolated.

Through further paper-based exploration, the measurement element was gradually reconsidered as something that should be physically integrated with the sampling component. As shown in Figure 8, this led to the development of a more compact measurement cup that could be stored in direct relation to the sample container, establishing an early direction toward a more unified system.

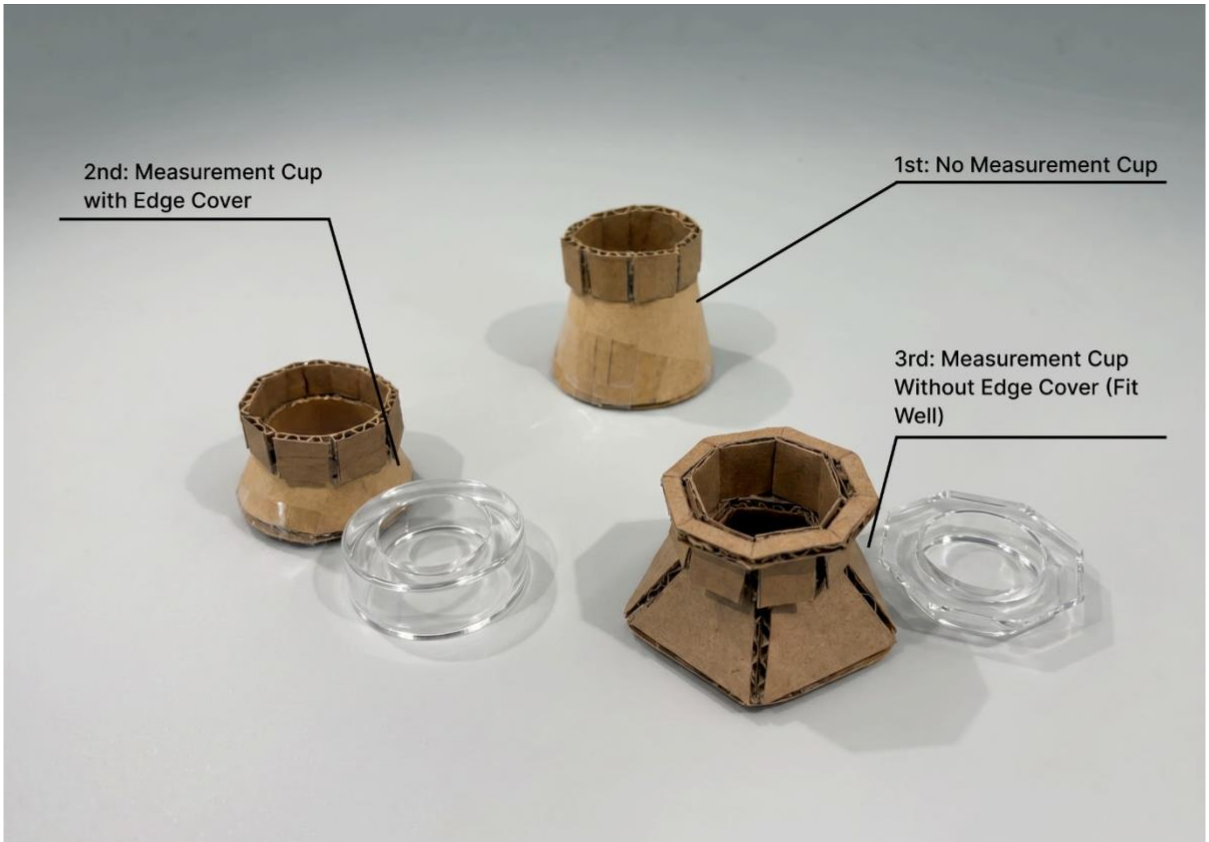

Figure 8 Measurement cup and Sample cup Development

Through these iterative explorations, a vertically oriented configuration gradually emerged as the most effective overall direction. This orientation aligned more naturally with the posture of the wrist when applying downward force on a surface and also established a clearer spatial relationship between the handheld component and the sampling component positioned below. At this stage, the form was not yet structurally finalized, but the exploration had already established several key directions for further development: a handle dimension of approximately 50 mm, a faceted yet softened geometry to improve grip stability, a vertically oriented testing posture, and a closer formal relationship between measurement and sampling components. These outcomes provided the basis for the next stage, in which the prototype began to be developed as a more resolved physical system.

4.3 Physical Prototype

Following the form exploration stage, the design was further developed into a physical prototype in order to examine how the proposed system could be constructed, assembled, and operated in practice. At this stage, the focus shifted from general form direction to the realization of structural relationships between the main components, including the device body, the sample container, and the measurement element. In this sense, physical prototyping functioned not simply as fabrication, but as a process of testing how earlier tangible design considerations such as grip, component clarity, sample handling, and controlled measurement conditions could be translated into a coherent physical system.

4.3.1 Physical System Components

The physical system was developed around four main components: an upper handle, a lower handle, a sample container, and a measurement cup, as shown in Figure 9. The upper and lower handles together formed the main body of the device, while the sample container and measurement cup supported sample collection and preparation within the broader interaction workflow. The main body was developed through iterative modeling and fabrication, primarily using 3D printing with PLA material, as shown in Figure 10. At this stage, PLA was used because it was accessible and practical for rapid iteration, allowing structural adjustments to be tested repeatedly as the prototype evolved.

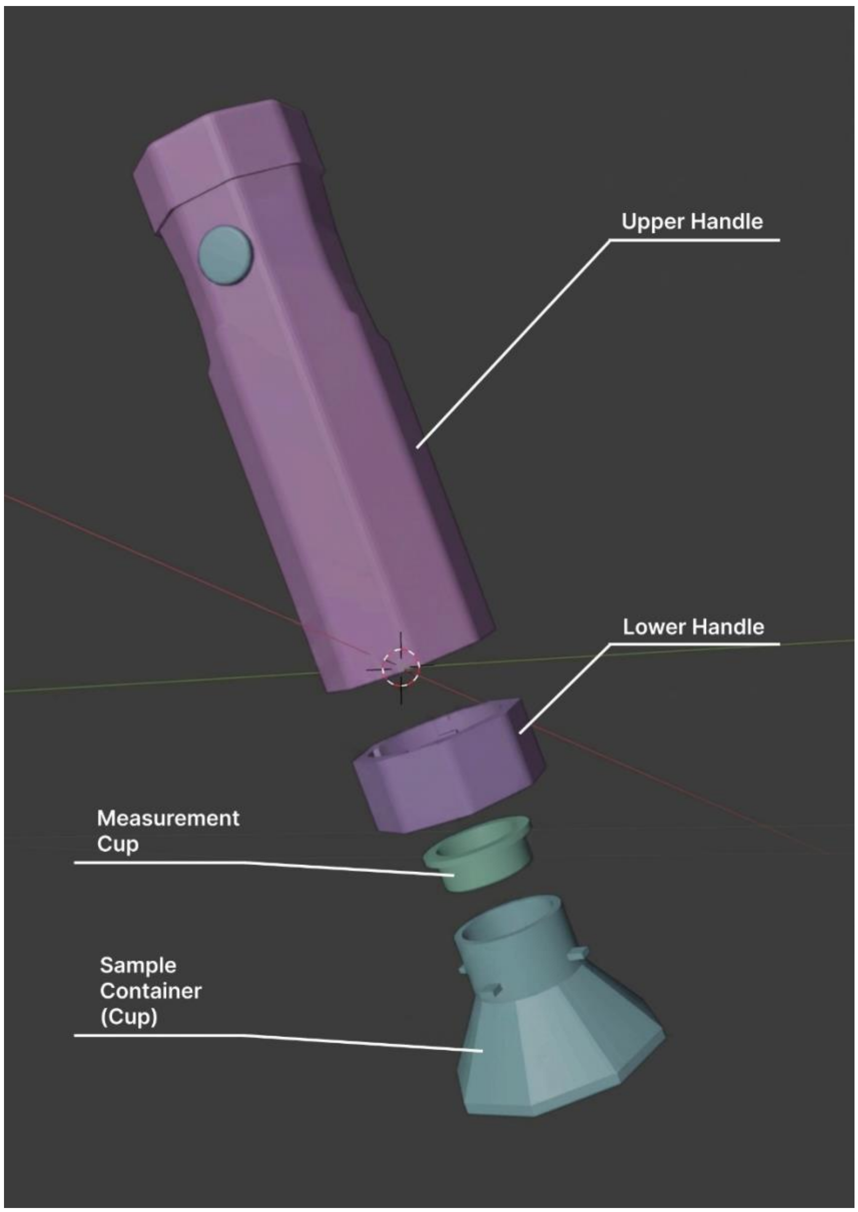

Figure 9 Physical System with Four Main Components

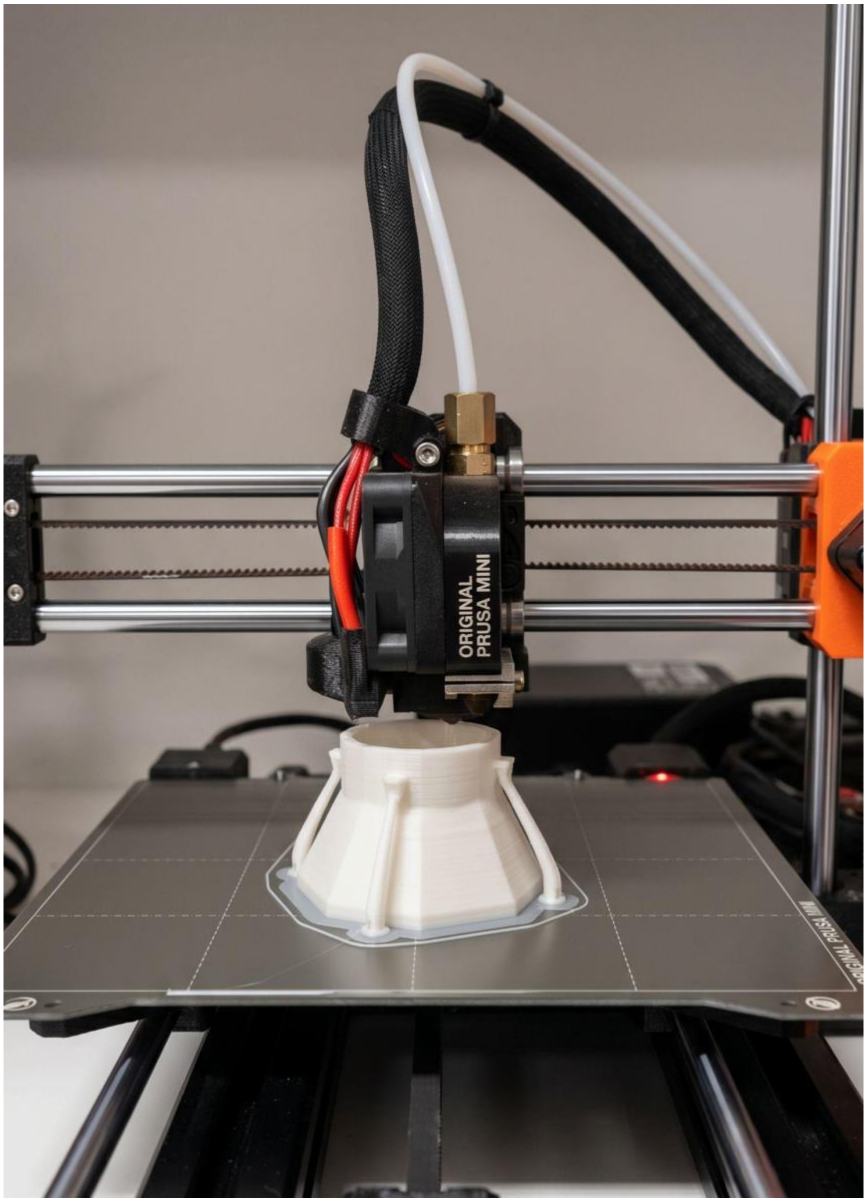

Figure 10 3D Printing Process with PLA Material

4.3.2 Opening Lid of Upper Handle

Particular attention was given to the design of the upper handle in order to support both assembly and iterative modification of the internal electronic components. In the initial iteration, the circuit could only be inserted from the bottom of the handle, which made it difficult to access or adjust once the upper and lower parts were assembled. To address this limitation, an opening was introduced at the top of the upper handle so that the circuit could be accessed independently of the lower structure. A simple sliding cover was then added to enclose this opening, as shown in Figure 11, balancing accessibility with structural continuity. This adjustment did not change the external interaction logic of the system, but it substantially improved assembly flexibility and made repeated testing and modification more manageable during development.

Figure 11 Upper Handle with Sliding Cover

4.3.3 Protection of Sensing Area

Another important part of the physical prototype concerned the protection of the sensing area from direct sample exposure. As discussed earlier in Section 2.3.1, sample-related design needs to consider not only handling and measurement conditions, but also food safety and contamination risk. Food-contact material selection and reusable sample components raise concerns related to hygiene, cleaning, chemical absorption, and possible migration during reuse (IFT Mantova, 2024, "Characteristics and advantages of food grade polypropylene" section; Tenhunen-Lunkka et al., 2023, pp. 44, 48, 52–53; Geueke et al., 2023, pp. 2, 13). In addition, stable gas-based measurement depends on appropriate sampling conditions, including sufficient headspace volume and sample-to-container proportion. Bridge Analyzers' technical guidance on MAP headspace gas sampling notes that measurement accuracy can be affected by available headspace volume, package rigidity, and analyzer design, while headspace sampling guidance further recommends that the sample occupy approximately 10–50% of the vial volume to support volatile release and gas-liquid equilibrium (Bridge Analyzers, 2019, “Sample Volume Considerations” and “Gas Sampling Considerations for Rigid Containers” sections; “Basics of Headspace Sampling,” 2024, “Usage Method” section). In relation to these concerns, a breathable protective membrane was incorporated between the internal sensing area and the external sampling environment, as shown in Figure 12. This layer allowed gas to pass through while reducing the risk of liquid contamination reaching the sensor. The approach was informed by waterproof breathable membrane technologies, in which materials such as polytetrafluoroethylene can support selective permeability by allowing gas or water vapor transmission while preventing liquid water penetration (Chang & Liu, 2023, pp. 1–3). The inclusion of this membrane required further adjustment of the internal spacing within the lower handle so that sensor protection and airflow could both be maintained.

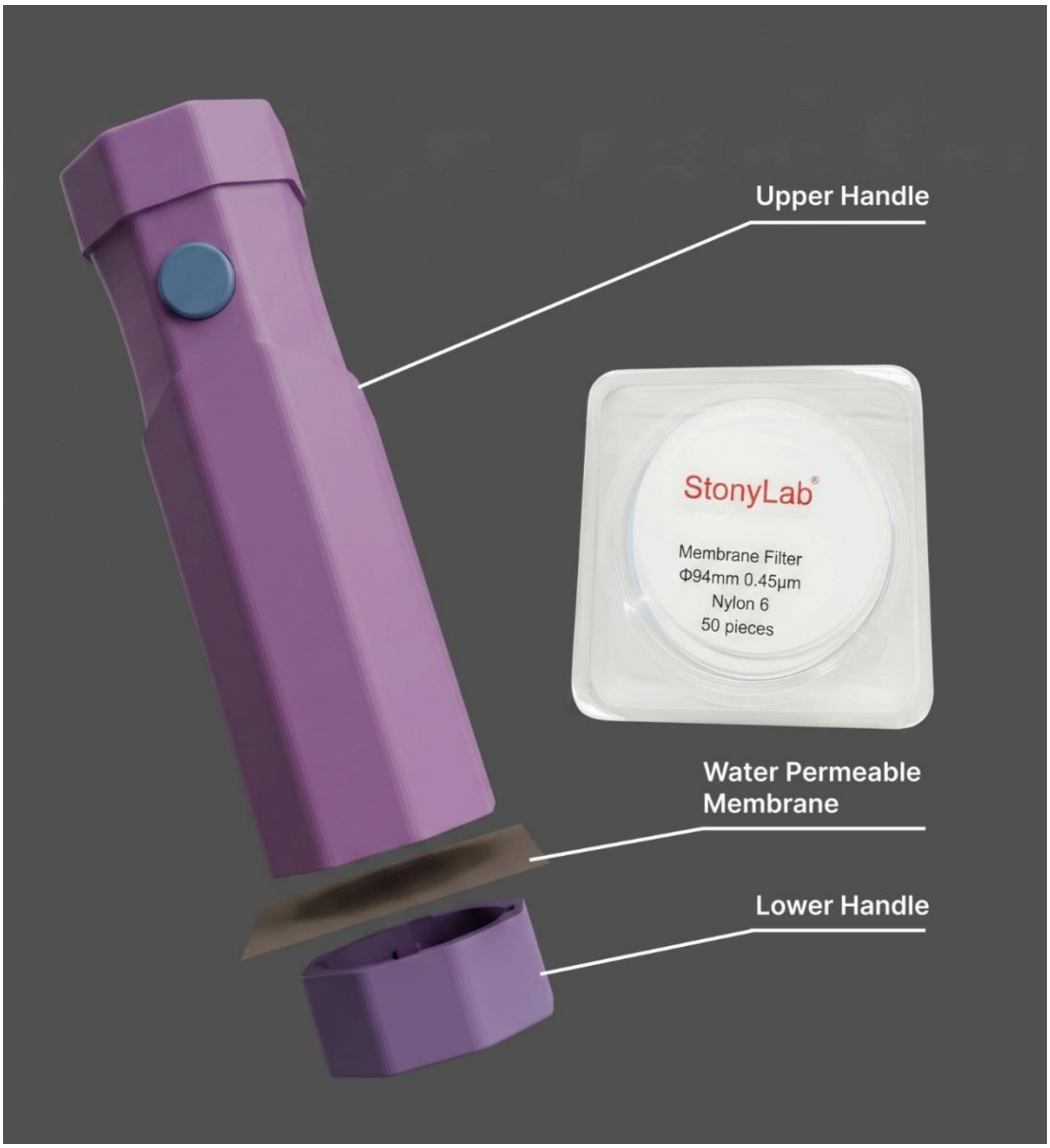

Figure 12 Position of Breathable Protective Membrane in Physical System

4.3.4 Development of Alignment Between Lower Handle and Sample Container

At the same time, the lower handle and the sample container required further refinement in order to support more stable attachment and more consistent alignment during use. Early physical iterations revealed several structural problems. Internal elements such as the spring and small locking parts within the alignment structure interfered with assembly, and insufficient clearance sometimes prevented proper engagement between components. In other cases, the protective internal space was too large, leading to misalignment and making it difficult for the handle to fully lock onto the container. To address these issues, multiple iterations of both the lower handle and the sample container were produced, including approximately two versions of the handle and three to four variations of the container. These iterative adjustments are shown in Figure 13. Across these versions, dimensions of the alignment grooves, the positioning of internal components, and the height of the protected sensing area were gradually refined in order to improve compatibility between parts and reduce assembly conflicts.

Figure 13 Variations of Sample Containers (Cups) and Lower Handles

This process eventually led to the development of a spring-loaded rotational locking structure in the lower handle. In exploring this mechanism, a kitchen juicer was used as a practical reference for how a handheld component could be pressed downward and rotated into position through a familiar domestic interaction pattern, as shown in Figure 14. Using a 3 mm diameter spring and a small internal locking component, the resulting structure was developed to simulate a twist-lock interaction similar to those found in everyday kitchen appliances. This allowed the handle to be pressed downward and rotated into position, producing both tactile and sound feedback while also creating a more secure connection between the device body and the sample container. In addition to improving usability, this mechanism supported more consistent alignment and helped maintain a semi-enclosed environment during testing. In this way, the locking structure addressed both interaction clarity and the physical conditions required for a stable assessment process.

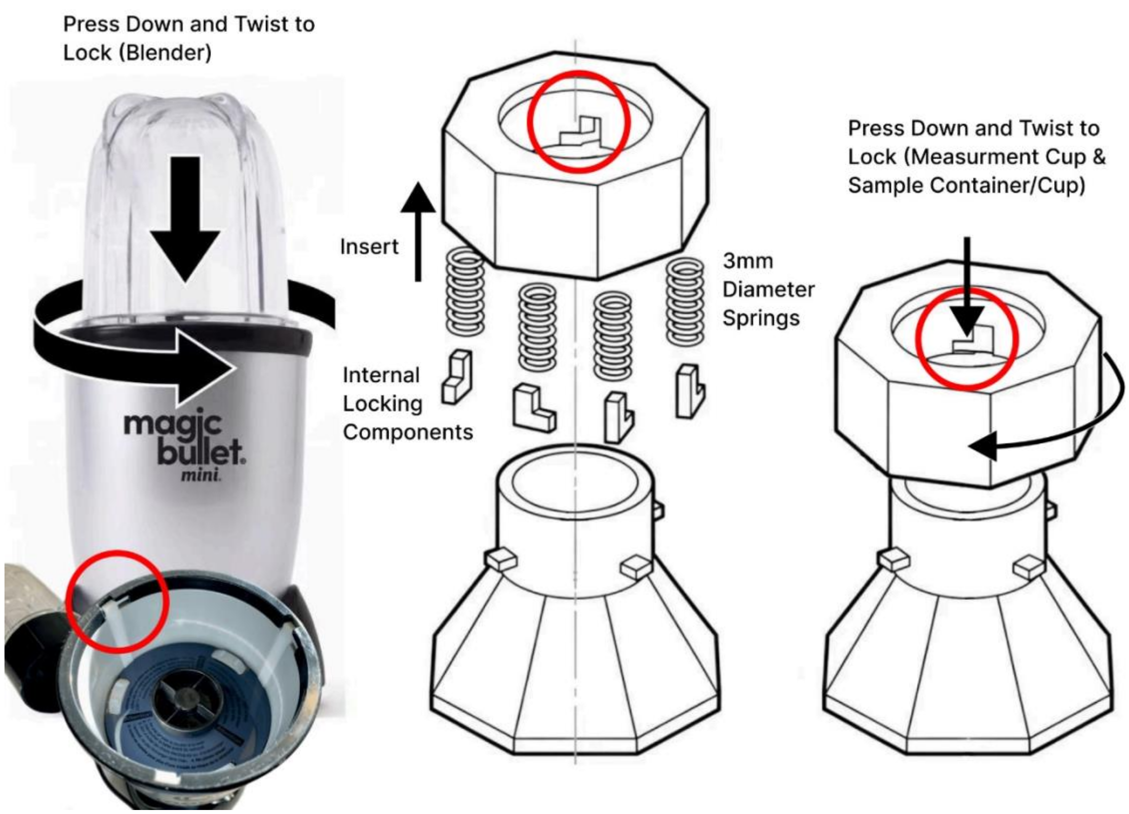

Figure 14 Lower Handle Structure and Locking Mechanism with Reference from Blender

4.3.5 Fitness Between Measurement Cup and Sample Container

Building on the integration explored earlier during form exploration, the sample container and measurement cup were also developed as interconnected components rather than as fully separate tools. As shown in Figure 15, the measurement element was refined into a compact component that could be stored in direct physical relation to the sample container when not in use. This decision responded to the earlier concern that a separate measurement cup appeared too isolated from the rest of the system and risked becoming visually or functionally disconnected from the sampling workflow. By bringing these two parts into a closer formal relationship, the prototype moved toward a more cohesive overall structure while also reducing the likelihood of the measurement element being misplaced or interpreted as unrelated to the system.

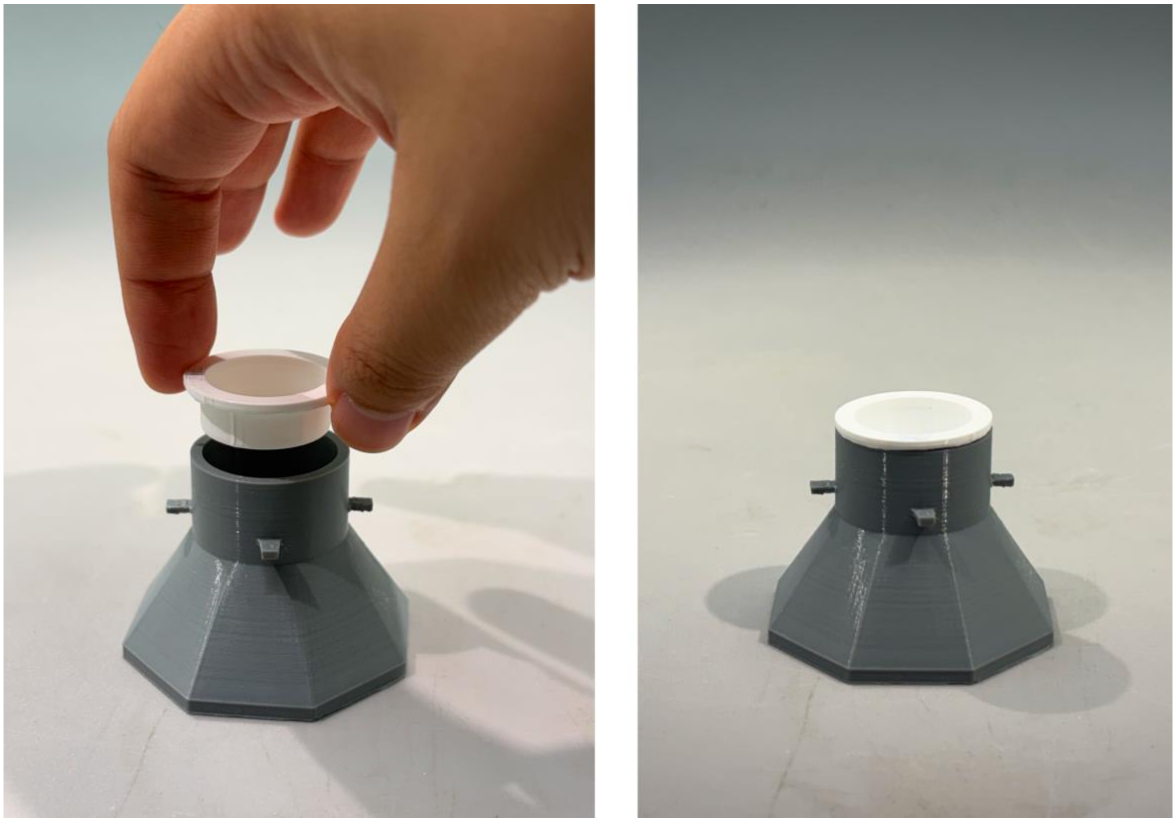

Figure 15 Measurement Cup and Sample Container (Cup)

Taken together, these developments show how the prototype evolved from an initial structural concept into a more resolved physical system. Through iterative fabrication and refinement, a number of key issues related to accessibility, alignment, protection, and integration were progressively addressed. The outcome of this stage was not yet a fully finalized product, but a sufficiently developed physical prototype that could support the next stage of development, namely the implementation of functional simulation and interactive system behavior.

4.4 Functional Simulation

Following the development of the physical prototype, the next stage focused on implementing a functional simulation system that could support interaction testing in a controllable and repeatable way. In keeping with the scope of the study, this stage did not aim to validate real spoilage detection accuracy. Instead, its purpose was to allow the prototype to produce interpretable states and feedback during use so that the interaction process could be tested in practice. In this sense, the functional simulation served as a bridge between the physical prototype and later user testing, enabling the evaluation of interaction clarity and user understanding without requiring scientifically validated sensing performance.

4.4.1 Gas Sensor Selection

The simulation system was developed around a compact electronic setup embedded within the device. To simulate sensing input, an MQ-3 sensor from the metal oxide semiconductor sensor family was selected as the core detection component, as shown in Figure 16. Although the MQ-3 is typically used for alcohol detection rather than dairy spoilage specifically, it provided a responsive and controllable signal suitable for prototyping. In this study, alcohol was introduced through a spray method so that system responses could be triggered in a consistent and repeatable way, allowing the interaction logic of the prototype to be tested without depending on unstable real-world spoilage conditions.

Figure 16 MQ-3 Sensor

4.4.2 Feedback Component Selection

Output was implemented through a multimodal feedback strategy combining visual, auditory, and haptic channels. A four-pin RGB LED was used to represent system states through color and blinking patterns, a passive buzzer was used to generate sound feedback through variation in tone and rhythm, and a vibration motor was incorporated to provide haptic output. Additional transistor and diode components were included to enable controlled activation of the vibration motor and variation in intensity and duration. By coordinating these modalities, the system was able to communicate different states without relying on a single sensory channel. These mappings were documented in the multimodal feedback reference sheet later provided during user testing, as discussed earlier in relation to *Appendix C: Device State Reference Sheet*.

4.4.3 Power Supply and Circuit Prototype

The system was built on an Arduino Nano microcontroller, selected for its compact size and compatibility with the spatial constraints of the upper handle. While alternatives such as the Arduino Uno offered more flexible power options, their larger size made them less suitable for integration within the available enclosure. To meet the 5V requirement of the MOS sensor, a 3.7V Li-Po battery was combined with a voltage booster module to provide a stable power supply. Because of the limited internal space within the upper handle, a traditional prototyping board was also unsuitable for circuit assembly. Instead, a compact perf board was cut to size so that the circuit could be integrated more effectively into the device enclosure. The resulting circuit assembly is shown in Figure 17.

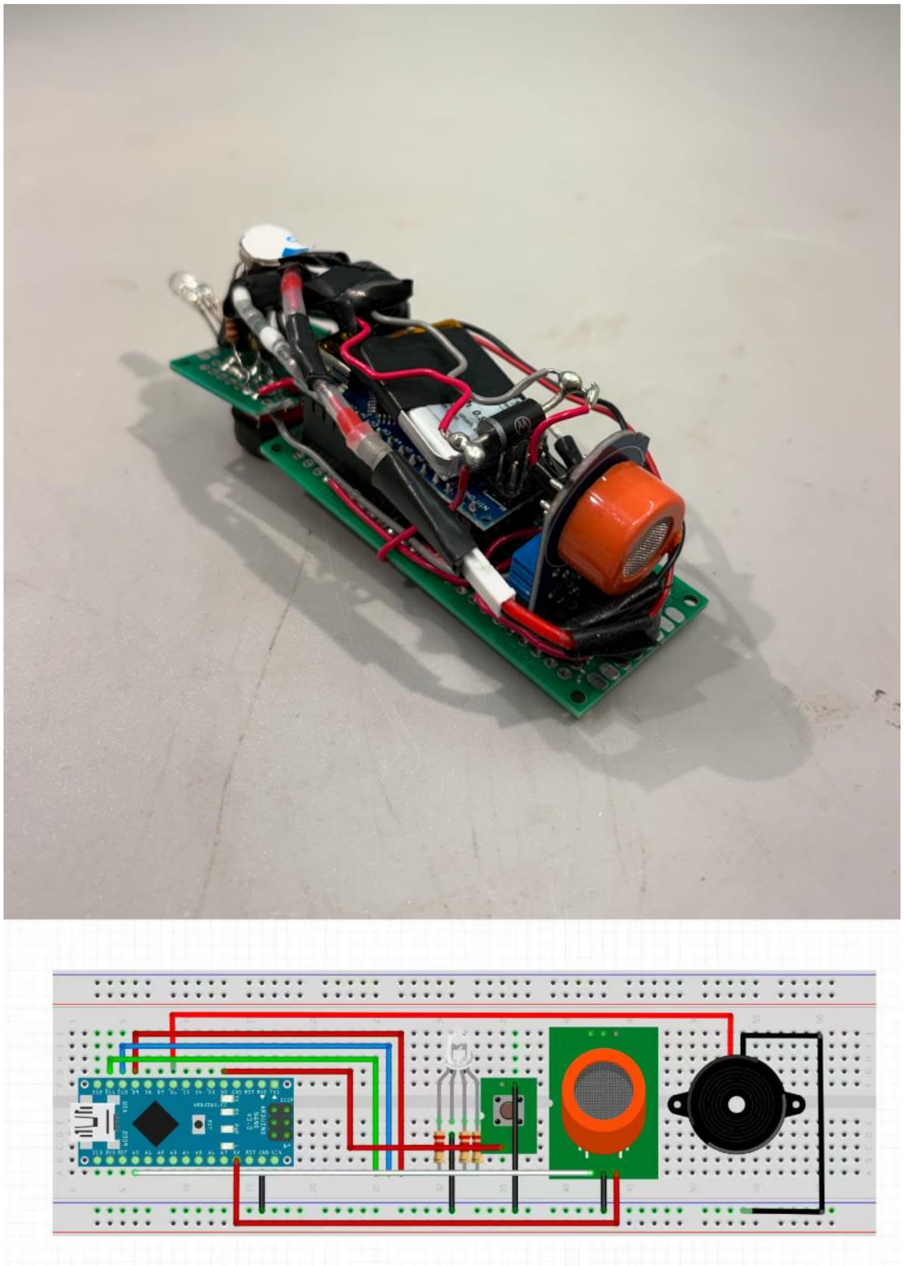

Figure 17 Circuit and Assembly

4.4.4 Coding for the Circuit

To implement the interaction logic, the Arduino code was developed with the assistance of ChatGPT (OpenAI, 2026). The tool was used to support code drafting and debugging, while the intended system states, feedback mappings, and interaction logic were defined by the researcher. AI-assisted coding was therefore used to translate the predefined state transitions and multimodal feedback structure into executable behavior for the prototype, allowing these outputs to be triggered in a controllable and repeatable manner during testing. In this sense, AI served as a technical support tool during implementation rather than as a source of design logic, which remained grounded in the predefined system structure and multimodal communication strategy established earlier in the project.

Within this implementation, several categories of interaction states were defined, including system states, process states, and outcome states. System states referred to conditions such as power off and readiness, process states referred to ongoing actions such as testing, and outcome states referred to the interpreted results of the assessment, including safe, warning, and error conditions. Each state was associated with a specific combination of visual, auditory, and haptic outputs, allowing the prototype to simulate not only detection activity, but also the broader communication logic required for later interaction testing. In this way, the functional simulation did not operate as a stand-alone technical demonstration, but as a supporting layer that made the embodied interaction of the prototype testable as a system.

Through this stage of development, the physical prototype was extended into a working interactive device capable of producing controllable input-response behavior. It established the operational logic through which system states could be experienced during use and therefore provided the necessary basis for the next stage of development, namely the design of the supporting application interface.

4.5 App Interface

As discussed in Section 4.1.2, the system was configured as a combined device-and-application structure because contextual input was necessary, but placing this input directly on the physical device would have increased interaction complexity and cognitive burden. The application was therefore developed as the part of the system responsible for receiving and organizing product-specific information before testing, while the device remained the primary site of embodied interaction and immediate multimodal feedback. In this sense, the app was not introduced as an additional convenience feature, but as a necessary component of the overall system configuration.

Based on this decision, the development of the application began with a comparative review of existing companion applications that work together with external devices. This review focused on app types that, although not designed for dairy spoilage assessment specifically, offered useful points of comparison for understanding how applications can support hardware systems through data display, device control, configuration, or interpretation. Several categories of examples were examined, including data-driven food quality applications, Bluetooth sensor applications, appliance-control applications, and device-configuration applications. These comparisons revealed that many existing applications either focused too heavily on raw data presentation, relied on predefined modes, or required users to interpret technical information independently. For the purposes of the present study, these tendencies were not sufficient, because the app needed to support context-dependent interpretation while reducing rather than increasing user responsibility.

In response to these observations, a features requirements table was developed to identify the functions that the application needed to support. This table did not simply collect desired functions, but translated the shortcomings identified through the assessment of alternative approaches, together with the needs established earlier in the study, into a structured set of functional and non-functional requirements. Features such as selecting the dairy product type, linking that selection to the internal detection logic, confirming the active product context, preventing misuse, maintaining a minimal interaction flow, and supporting Bluetooth connection were treated as core requirements. Other features, such as user-contributed reference data, anonymous contribution, in-app instructions, and interface customization, were also identified but positioned as more extended possibilities. To make these distinctions explicit, each feature was assigned a priority level, such as Must or Ideal, according to its necessity for the prototype and its relevance to the broader system vision. The full assessment of alternative approaches together with the complete application requirements table is provided in *Appendix L: Alternative Approaches Assessment and Application Feature Requirements*.

Once these features and priorities had been established, they were reorganized into an information architecture using the structured visual vocabulary proposed by Garrett (2002). As shown in Figure 18, the resulting workflow diagram mapped how the app's features were related to one another and how they might be organized within the broader system. Rather than representing only the final implemented screens, this diagram functioned as a structural planning tool. It showed the main testing-related path, including Bluetooth pairing, dairy selection, current target confirmation, and result return, while also locating additional modules such as upload, settings, and help within the overall architecture. Color coding was used to distinguish feature types and levels of priority, making it possible to clarify which functions were essential to the core testing flow and which remained part of a broader design vision. In this way, the workflow diagram helped translate the requirement table into a more spatial and relational organization of the system.

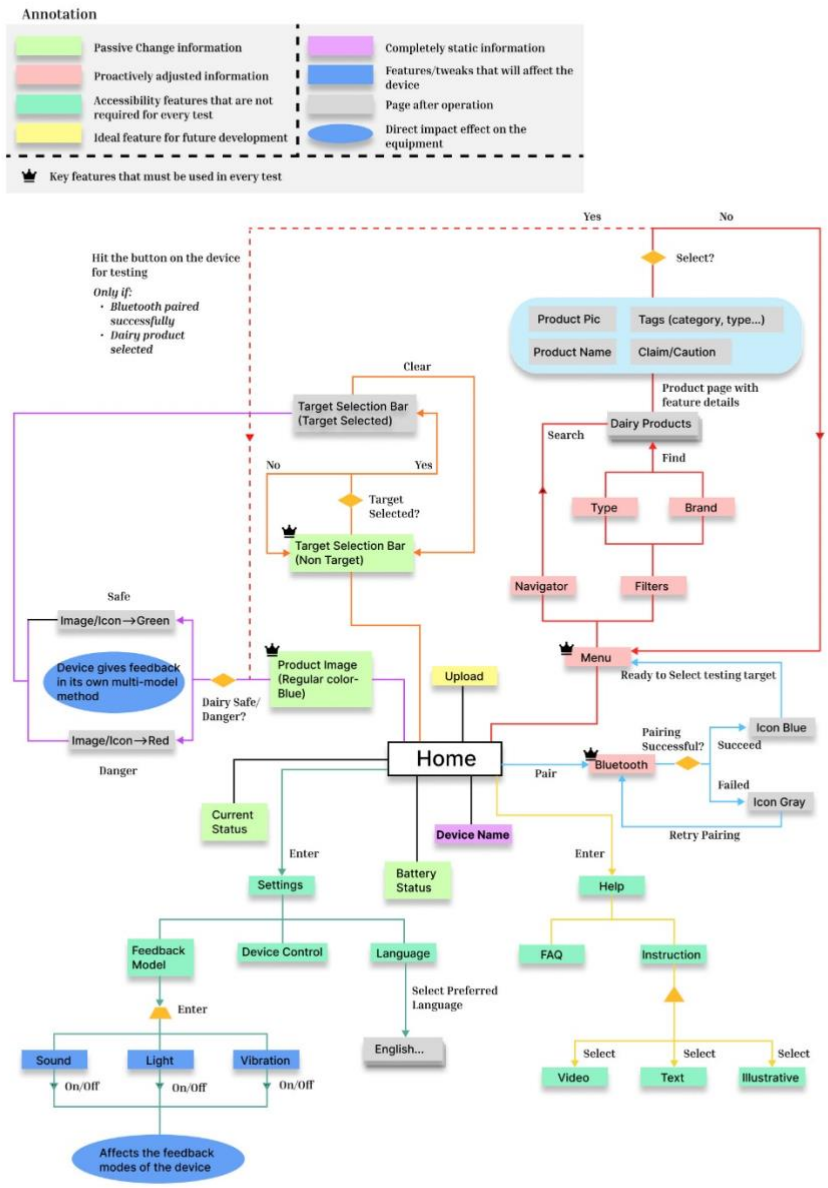

Figure 18 Workflow Diagram of the App

Following this structural mapping, low-fidelity interfaces were developed in Balsamiq to define the layout and organization of interface elements, as shown in Figure 19. At this stage, the focus was placed on the arrangement of key components, the hierarchy of information, and the sequence of user actions rather than on visual polish. The low-fidelity interfaces made it possible to test how users might move through the app's core functions, how contextual input could be presented, and how unnecessary complexity could be reduced before further development.

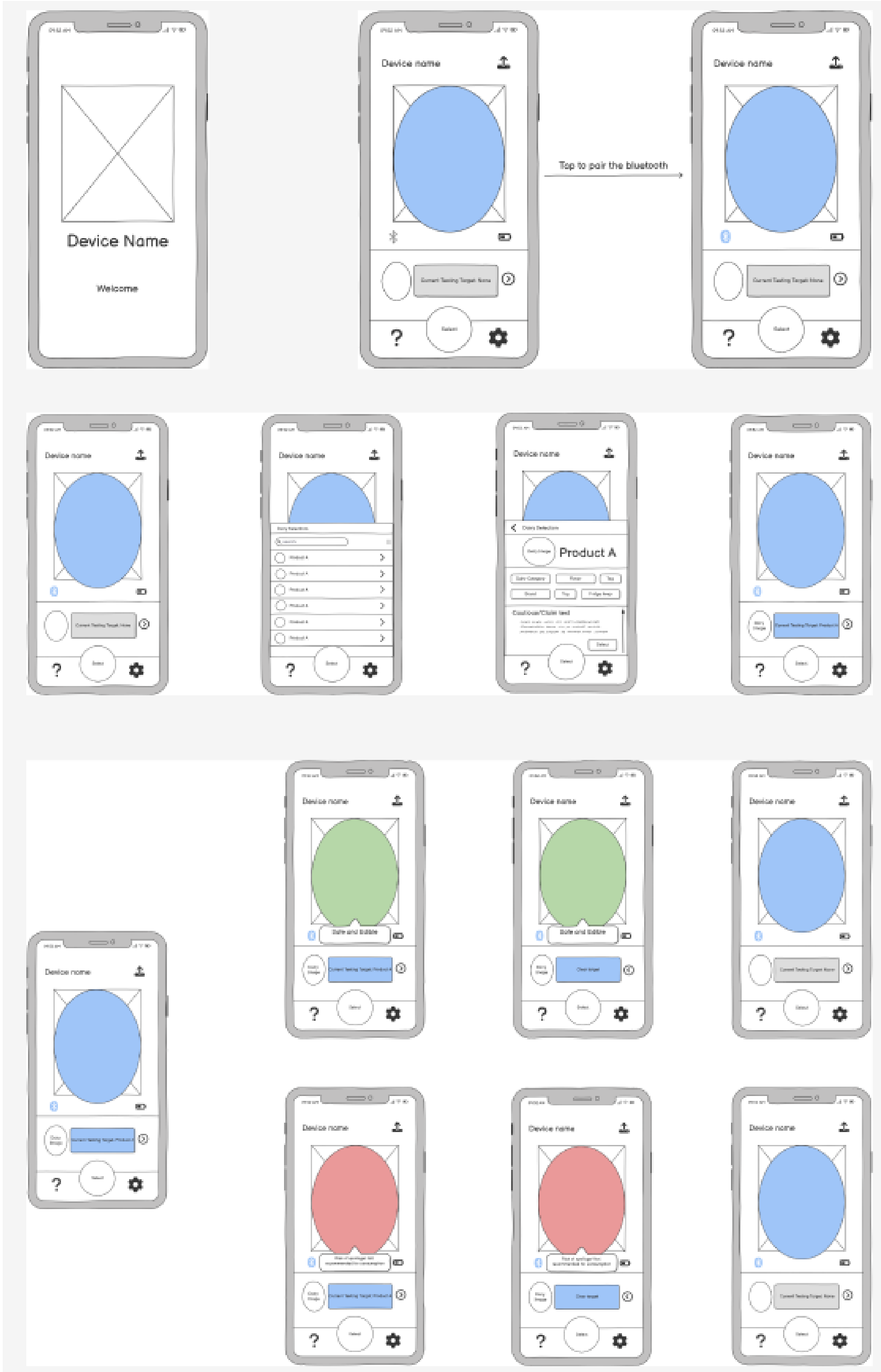

Figure 19 Low-Fidelity Interfaces

Building on this foundation, a mid-fidelity interactive prototype was then developed in Figma, incorporating basic animations and transitions to simulate interface behavior, as shown in Figure 20. This stage allowed the app to move beyond a static structural plan and become an interactive layer that could be used in later testing. The prototype focused on the essential flows associated with product selection, test initiation, and result display, rather than attempting to implement every feature identified in the earlier requirement table. This selective implementation was consistent with the requirement of maintaining a minimal interaction flow while ensuring that the app could still support the device as an information input and interpretation layer.

A set of mid-fidelity mobile app interface screens created in Figma shows a more detailed version of the companion app workflow. The screens include the welcome page, Bluetooth connection status, device home screen, dairy product selection list, product information page, testing target selection, and testing feedback states. The interface uses visual feedback to show different results, including safe status, no sign of spoilage, and potential spoilage detected.

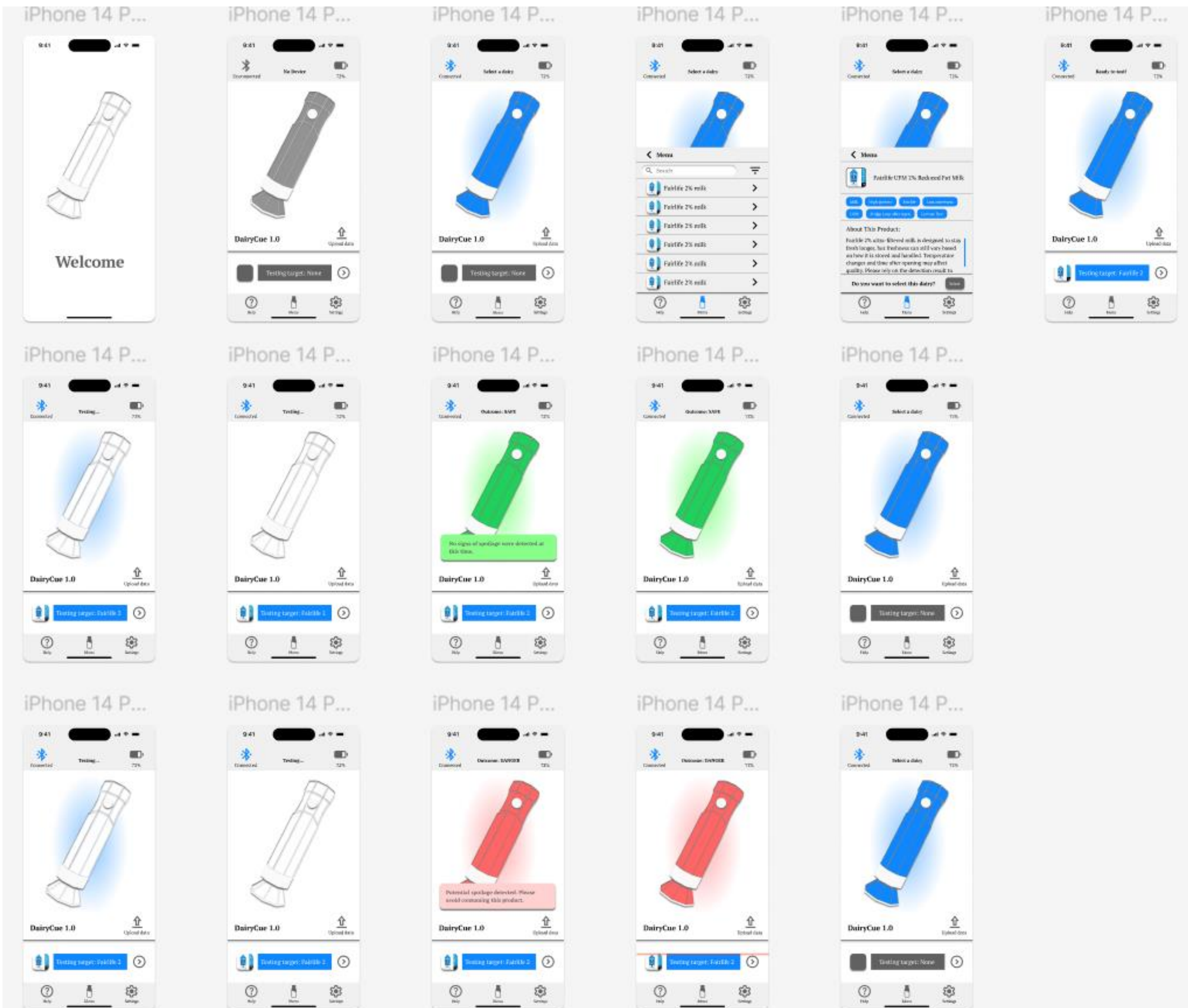

Figure 20 Mid-Fidelity Interfaces

Through this process, the application developed from a necessary system-level decision into a structured and testable interface component. Its final role within the prototype was not to replace the handheld device as the main interaction point, but to complement it by handling contextual input and providing a more explicit layer of information organization. In this way, the app completed the digital side of the prototype system and established the basis for the integrated prototype described in the following section.

4.6 Prototype Development Summary

Through the stages described above, the project moved from initial form exploration and structural experimentation to a more resolved prototype system prepared for user testing. Rather than functioning as separate developments, the form, physical construction, functional simulation, and application interface gradually converged into one integrated prototype. As a result, the outcome of this chapter is not only a set of individual components, but a coherent system in which physical interaction, contextual input, and multimodal communication are designed to work together.

As shown earlier in Figure 2, the prototype was organized around several interconnected parts, including the handheld device body, the sample-related components, and the supporting application. While Figure 2 presents the structural relationships of these parts in exploded form, the completed prototype in its assembled state is shown in Figure 21.

Figure 21 Completed Prototype with App

At the level of interaction, the handheld device functions as the primary physical touchpoint of the system. It supports the core embodied actions required during testing and communicates immediate system states through multimodal feedback. The sample container and measurement cup support the preparation, transfer, and controlled holding of the sample as part of the broader testing workflow. The application complements these physical components by handling contextual input and providing a more explicit layer of information organization and result interpretation. In this way, the prototype does not divide functions arbitrarily across physical and digital components, but distributes them according to the different interaction demands identified earlier in the study.

What emerges from this process is a prototype that reflects the main design decisions established in Section 4.1 and the subsequent development work described in Sections 4.2 to 4.5. The selected detection direction shaped the need for controlled sampling and simulation. The combined device-and-application configuration shaped how interaction responsibilities were distributed across the system. Earlier tangible and intangible design considerations were then materialized through the physical structure, the functional logic of the device, and the interface of the app. In this sense, the prototype can be understood not as a finalized product, but as a materially realized design proposition that brings together the conceptual, technical, and interaction-related decisions made throughout the study.

By the end of this chapter, the prototype had reached a state that was sufficiently developed to support structured user engagement. The next chapter therefore shifts from prototype development to system integration, focusing more specifically on how the components operate together within the overall interaction flow.

5.0 System Integration

With the prototype components established through the development process described in Chapter 4, the next step is to examine how they function together as one coordinated system during use. At this stage, the focus shifts from the separate development of form, structure, simulation, and interface to the complete interaction process through which users engage with the prototype in practice. The following section therefore presents the integrated interaction flow of the system, showing how the handheld device, sample-related components, and supporting application operate together across the full testing sequence.

The interaction flow of the system is organized as a sequence of coordinated actions between the physical device and the mobile application, guiding users from device activation to result interpretation and system reset. As illustrated in Figure 22, this process unfolds through six main stages, beginning with powering on and Bluetooth connection, followed by sample preparation and attachment, context specification through the app, test initiation, result presentation and interpretation, and the completion of the interaction cycle through reset and shutdown. The following paragraphs describe each of these six stages in detail.

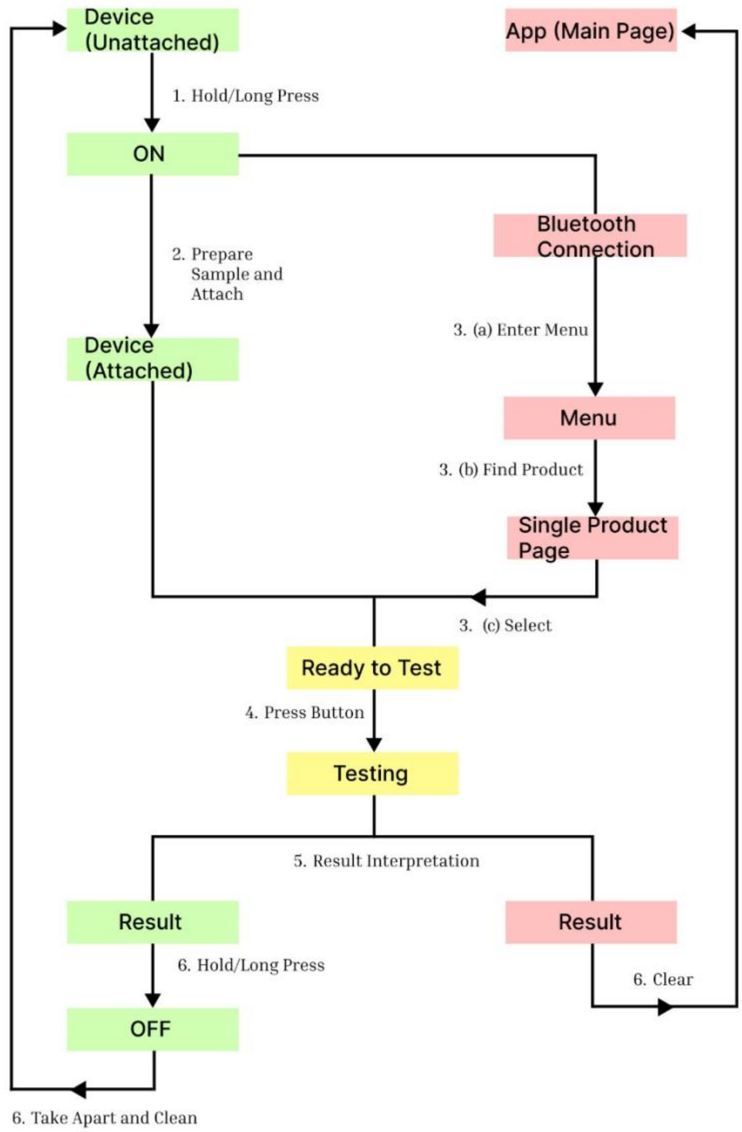

Figure 22 Workflow between Device and App

Step 1: Device activation and system initialization

The interaction begins with powering on the handle through a press-and-hold action on the main button. Upon activation, the system emits a short tonal sequence, such as a do–re–mi–do pattern, accompanied by low-intensity vibration pulses, signaling that the device has been turned on. At the same time, the LED on the handle begins to blink in blue, indicating that the system is attempting to establish a Bluetooth connection.

Once the connection is successfully established, the system emits a confirmation sound accompanied by short vibration feedback, while the LED transitions to a stable blue state. This change indicates that the handle and the mobile application are successfully paired. In parallel, the application reflects this process through synchronized visual changes: the device representation transitions from an inactive state to a blinking blue state with a halo effect, and then to a stable blue display upon successful connection, while the Bluetooth icon updates to indicate a connected status. These coordinated signals across modalities and platforms provide users with clear confirmation of system readiness.

Step 2: Sample preparation and physical setup

Users prepare the dairy sample using the measurement cup and transfer it into the sample container. The consistent use of a defined sample volume supports a stable relationship between sample quantity and container capacity, reducing uncertainty during preparation.

The sample container is then aligned with the handle through a set of corresponding protrusions, allowing it to be pressed downward and rotated into position. This interaction results in a temporary locking state that secures the connection between the handle and the sample container, forming a semi-enclosed environment for sensing. While not fully sealed due to material constraints, this configuration enables stable containment of the sample and supports reliable detection of its gaseous properties. At this stage, the physical setup of the sample is complete, and the system is ready for testing.

Step 3: Context specification through the application

Following the preparation of the physical components, users define the testing context through the mobile application. This step enables the system to align the evaluation process with the selected dairy product by transmitting the corresponding contextual information to the device. Users access the menu from the bottom navigation area and select the desired testing target, which opens a dedicated product page containing relevant information about the selected item, including basic descriptors and characteristic tags.

Upon confirming the selection through a dedicated action on the product page, the interface returns to the main screen. The previously inactive target selection bar becomes highlighted, displaying the selected product name and a corresponding visual identifier. At the same time, the status indicator at the top of the interface signals that the system is ready for testing. These coordinated interface changes provide clear confirmation that the testing context has been successfully defined and that the system is prepared for the next stage of interaction.

Step 4: Test initiation and measurement process

Once all preparation steps are completed, the test is initiated through a single press of the main button on the handle. This action triggers the system to enter an active measurement state, marking the transition from preparation to detection.

During this phase, the handle communicates the ongoing process through a coordinated set of multimodal signals. A brief white light indicates that measurement is in progress, accompanied by two short, low-intensity auditory signals delivered in quick succession, followed by a longer vibration pulse. This combination of signals distinguishes the measurement state from both activation and result feedback. In parallel, the mobile application reflects this transition through synchronized visual changes. The device representation shifts from a stable blue state with a halo effect to a white display, with the disappearance of the halo indicating a transition from standby to active processing. These coordinated signals across physical and digital interfaces communicate that the system is actively evaluating the sample.

Step 5: Result presentation and interpretation

Upon completion of the measurement, the system transitions from the active testing state to result presentation. Both the handle and the mobile application simultaneously communicate the outcome, allowing users to interpret the condition of the dairy sample through coordinated multimodal feedback. In the testing setup, different outcomes can be intentionally triggered, enabling participants to experience both safe and potentially unsafe conditions during evaluation.

The handle communicates the result through distinct combinations of visual, auditory, and tactile signals. A safe condition is indicated by a stable green light, accompanied by two soft auditory signals delivered at a slower interval and two longer vibration pulses. In contrast, a potentially unsafe condition is indicated by a flashing red light, accompanied by a sequence of faster, sharper auditory signals and shorter, more frequent vibration pulses. These contrasting signal patterns are designed to convey different levels of urgency and allow users to distinguish outcomes through perception alone. In parallel, the mobile application reflects the result through synchronized visual feedback, with the device representation changing to the corresponding color state and a contextual note presented to support interpretation. Together, these signals provide both immediate perceptual cues and explicit confirmation of the test result.

Step 6: Reset and completion of the interaction cycle

Although the testing process concludes with the presentation of the result, the system retains the previously selected testing context within the application. To prepare for subsequent use, users are required to manually clear this state by activating the reset function located within the target selection interface. This action removes the current selection and returns the application to its initial condition, ensuring that no residual context remains for the next test.

On the device side, users power off the handle through a press-and-hold action, similar to the activation process. The system provides a distinct shutdown signal, consisting of a prolonged auditory tone accompanied by a sustained vibration pulse, indicating that the device has been turned off. The sample container can then be detached from the handle and returned to its resting state. Together, these actions complete the interaction cycle, restoring both the physical and digital components to a neutral state in preparation for subsequent use.

The six-step interaction sequence described above also forms the basis for the structured user testing tasks developed in this study. During user testing, participants were guided through a predefined scenario consisting of six corresponding tasks, each aligned with a specific stage of the interaction flow. This alignment ensured that user testing followed a controlled yet representative interaction sequence, allowing the study to examine how participants interpreted system states, navigated the workflow, and responded to multimodal feedback.

6.0 Findings and Discussions

This chapter presents both the findings and the design insights generated through the two data collection activities used in the study: in-person user testing and the online survey. As described in Chapter 5, the integrated interaction flow of the prototype was organized into six stages, and these same stages formed the basis of the structured user testing tasks used in the study. The user testing results presented here therefore emerge from participants' engagement with the prototype through that designed interaction sequence, while the survey results provide a broader set of user perspectives collected outside the direct testing context. Together, these materials form the basis for both the findings reported in this chapter and the design insights derived from them.

Building on the data collection and analysis methods outlined in Chapter 3, this chapter is organized in two stages. Section 6.1 presents the findings derived from user testing and survey materials, while Section 6.2 translates these findings into design insights that can support future refinement of the system. In this way, the chapter moves from observed interaction and user responses to the implications these results hold for the next iteration of development.

6.1 Findings

This section presents the findings generated through the two data collection activities used in the study: in-person user testing and the online survey. Because these two methods produced different kinds of material, their findings are presented separately. As outlined in Section 3.2, the materials collected through these activities were analyzed and organized into a structured and interpretable body of findings rather than presented as raw feedback. The user testing findings are based on participants' engagement with a set of six structured tasks developed for the testing sessions, as outlined in *Appendix B: Testing Protocol*. These tasks were derived from the interaction flow described in Chapter 5, but were adapted into a scenario-based testing process situated in a kitchen context. The survey findings, by contrast, focus on broader user preferences and expectations related to handheld kitchen tools and everyday use. Together, these two sets of findings provide both interaction-specific observations and wider contextual perspectives that inform the later design insights.

6.1.1 Findings From User Testing

As outlined in *Appendix F: Coding*, the in-person user testing materials were organized into six thematic groups: ergonomics and physical comfort, device operation, sample preparation process, app interaction, feedback interpretation, and user expectations, perceptions, and suggestions. The relationships between these six groups and their corresponding coded themes are illustrated in Figure 23. The findings presented below are based on this coding structure and draw on both the detailed participant-level records in *Appendix G: In-Person Feedbacks_DEVICE*, *Appendix H: In-Person Feedbacks_APP*, and *Appendix I: In-Person Feedbacks_OTHER*, as well as the cross-participant synthesis in *Appendix J: Feedback Summary*. Rather than presenting feedback participant by participant, this section reports the recurring patterns that emerged across the testing sessions.

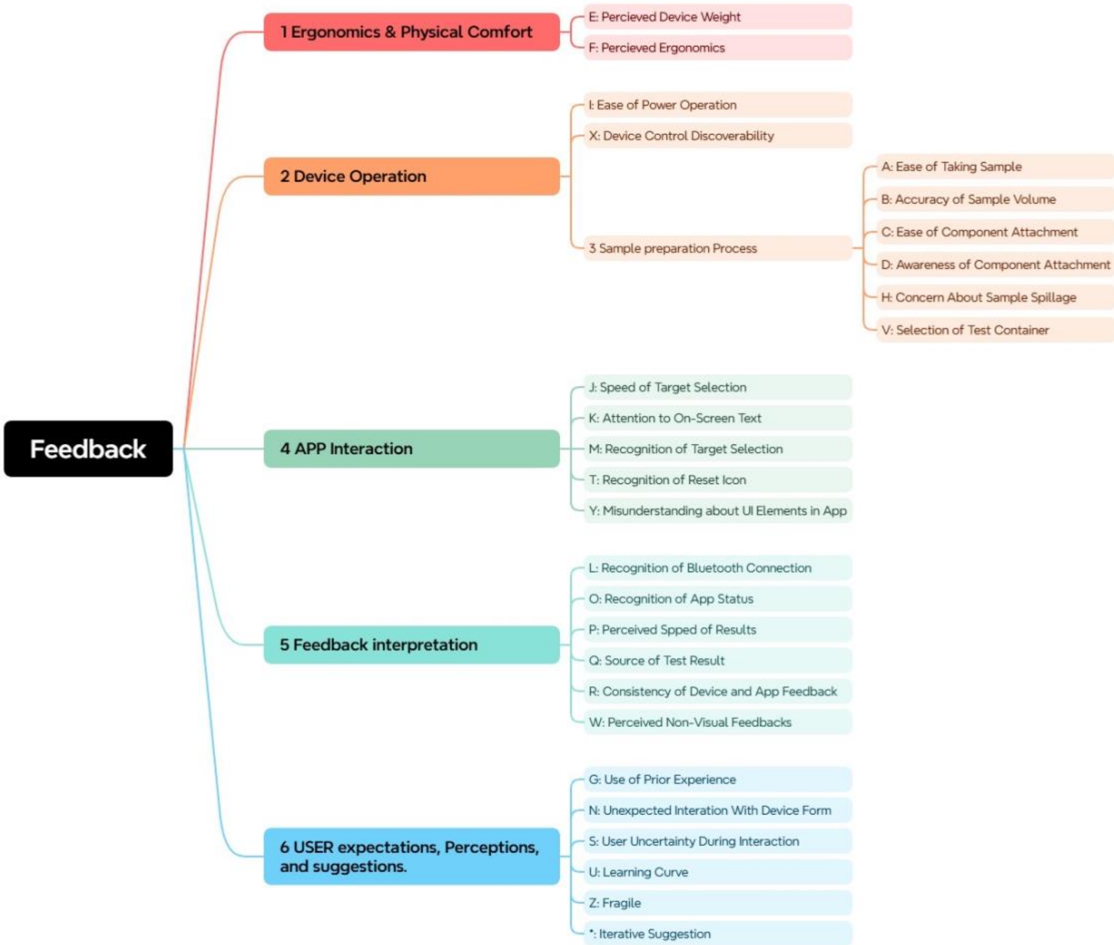

Figure 23 The Six Thematic Groups Used to Organize the In-person User Testing Findings and Their Corresponding Coded Themes.

Ergonomics and Physical Comfort.

Findings related to ergonomics and physical comfort show that the prototype was generally perceived as manageable in hand, but that component relationships also shaped participants' bodily interpretation of the device. In terms of weight, 2out of 9 participants explicitly described the device as light and easy to hold with one hand, while the remaining participants did not refer or mention weight in the feedback they provided. Ergonomic feedback was more varied. In 3 out of 9 cases, participants stated that their thumbs naturally fell onto the main button when they first held the handle, indicating that the control was easy to locate. At the same time, in 5 out of 9 cases, the close fit between the sample container and the measurement cup led participants to interpret the two parts as intended to be used together during testing.

One participant (p4) also described the locking mechanism as especially convenient for left-handed use. These results suggest that while the handle itself was often perceived as physically manageable, the formal relationship between components strongly influenced how users interpreted the physical logic of the system.

Device Operation.

Findings related to device operation indicate that the basic control logic of the prototype involved only limited misinterpretation during participants' initial exploration of the prototype, although first-time discovery still involved moments of exploration. For power operation,6out of 9 participants were able to power the device on and off directly and without major difficulty, while the remaining 3 out of 9 indicated that the action became easy after one round of exploration or practice. In terms of control discoverability,3out of 9 participants explicitly noticed the single button control immediately, and 7 out of 9 noticed the intended alignment relationship between the handle and the sample container. One participant interpreted the button as a speaker because of the printed surface texture; one participant initially read the device as flashlight-like, and another initially assumed that the handle itself was already a complete unit. Concerns about cleaning difficulty were also raised by 2 participants, particularly in relation to corners or internal surfaces. These findings show that the core operation of the device was not generally experienced as highly difficult, but that the prototype still prompted exploratory interpretation when participants first encountered its form and controls.

Sample Preparation Process

Among the six thematic groups, sample preparation generated the highest concentration of usability-related feedback. Participants frequently described this part of the process as demanding careful handling and attention. In relation to sample collection, 4 out of 9 participants described preparation as difficult because it required precise action, while 3 out of 9 explicitly commented that the measurement cup felt too small. One participant also raised a visibility issue in relation to the sample container, and another noted that the process could be especially difficult for users with visual impairments. Accuracy of sample amount was also mixed, with 5 out of 9 participants producing what was coded as an accurate sample amount and 4 out of 9 producing an inaccurate one. Component attachment showed a similarly divided pattern: 3 out of 9 participants attached components easily before and after applying the sample, 4 out of 9 found attachment difficult both before and after sample application, and 2 out of 9 found attachment easy before the sample was added but more difficult afterward. Even so, awareness of the intended connection between the handle and the sample container was relatively strong, with 8 out of 9 participants recognizing that the two parts were meant to be attached. Concern about spillage was one of the most common findings in this group, appearing in 6 out of 9 cases. Container selection also varied considerably: 5 out of 9 participants ultimately used the measurement cup as the testing container, 3 out of 9 used the sample container directly without measurement, and 1 out of 9 used the sample container while covering it with the measurement cup during testing. Altogether, these results show that the preparation stage was the least certain part of the interaction sequence, combining uncertainty about quantity, attachment, and component roles in a way that produced substantial variation across participants.

App Interaction

Compared with physical preparation and component handling, participants generally encountered fewer difficulties in the mobile application. In relation to target selection, 6 out of 9 participants selected the intended dairy product directly and smoothly, while 2 out of 9 completed the selection successfully only after initially tapping feature tags that they interpreted as selectable options. One participant completed the task successfully but more slowly than the others. Participants also engaged with the on-screen text in different ways. Four participants spent time reading the text information, one explicitly questioned whether that amount of text was necessary, and others relied more heavily on interface changes than on textual content. Recognition of successful target selection was relatively consistent, with 7 out of 9 participants noticing the change through the target selection bar and 2 out of 9 noticing it through the image change next to that bar. Recognition of the reset icon was especially strong, with all 9 participants tapping it directly and without explicit prompting when asked to clear the selected product. The main recurring misunderstanding involved product feature tags, which were interpreted as selectable attributes in 3 cases. Another participant interpreted the small image area near the target bar as a menu or overlay trigger. These findings suggest that the overall app flow was relatively consistent for participants, but that not all interface elements were interpreted in the same way when visual hierarchy made descriptive elements resemble interactive controls.

Feedback Interpretation

Feedback interpretation was one of the most consistently successful parts of the interaction. Recognition of Bluetooth connection often depends on either the blue-light status or reference to the *Device State and Feedback Reference Sheet (Appendix C)*. Six participants identified the connection through the blue light with the help of the reference sheet, while several others also recognized the state through changes in the app interface. One participant expressed an expectation for more explicit visual confirmation of Bluetooth status. Recognition of app status was more varied: some participants noticed it through the top status bar, others through the target selection bar, and several relied on the reference sheet to confirm status meaning. By contrast, perceptions of testing speed were highly consistent, with all 9 participants describing the result as smooth, quick, or immediate. Source of result interpretation was also clear: all 9 participants noticed the color change first and used it as the primary basis for understanding the outcome. In addition, 2 participants noticed the pop-up message in the app, and 4 explicitly referred to multimodal cues such as sound or vibration as part of their interpretation. Consistency between device and app feedback was recognized by 8 out of 9 participants. Non-visual feedback was noticed in more varied ways: 1 participant described the vibration as too strong, 2 felt vibration helped them rely less on vision, 1 noticed the power-on melody, 1 noticed the click sound for attachment, and 3 explicitly commented that sound and vibration matched the result state. Overall, these findings show that result communication was one of the clearest parts of the system, with visual feedback functioning as the dominant interpretive cue and the app and device generally reinforcing one another successfully.

User Expectations, Perceptions, and Suggestions

The final thematic group captured broader patterns related to prior experience, uncertainty, learning, and suggestions. Prior experience played a noticeable role in how participants interpreted the prototype. Examples included comparisons to cough-syrup measuring cups, flashlight-like handheld devices, scan-test tools, container lids, IKEA-style assembly, juice blenders, and familiar reset icons. These prior mental models sometimes supported understanding, but in other cases they contributed to unexpected interaction. Uncertainty during interaction appeared most often in relation to attachment, locking direction, sample amount, and how long the button should be held during power control. Learning effects were also present: 4 out of 9 participants explicitly stated that the interaction would become easier with repetition or practice, and 1 participant noted the importance of the cheatsheet in helping them understand system behavior. Concerns about fragility were rare but still present, with 1 participant explicitly expressing worry about breaking the prototype. Suggestions recorded during testing included making the measurement cup bigger, changing its form, making the target selection bar or selection button larger, making text information optionally visible, and adding a voice alert. Because these comments were recorded as part of the user testing data itself, they are presented here as findings rather than as adopted design directions. Taken together, this thematic group shows that participants approached the prototype not only through immediate interaction, but also through prior expectations, analogies, and reflections on how the system might behave with greater familiarity.

Across these six thematic groups, the findings show that the user experience of the prototype was unevenly distributed across the interaction process. Physical preparation and component handling generated the greatest variability and uncertainty, while app use and especially result interpretation were more consistently understood. This pattern is significant because it indicates that the prototype did not function as uniformly difficult or uniformly successful across all stages. Instead, different parts of the system produced different kinds of user response, revealing a more differentiated picture of how the prototype was experienced in practice.

6.1.2 Findings From Survey

The findings from the online survey were derived from the compiled responses presented in *Appendix K: Online Forms Responses*. Unlike the in-person testing materials, which focused on participants' interaction with the prototype itself, the survey collected broader references to handheld kitchen tools that participants already liked and used. Each response included an image of a preferred handheld kitchen tool together with a short explanation of why it was valued. These responses were initially organized into three broad descriptive categories during analysis: function, form, and aesthetics. At the same time, a further pattern related to material qualities also emerged repeatedly across responses during later review, even though material was not treated as a separate formal category in the initial classification. The findings presented here are therefore not interaction findings in the same sense as the user testing results, but rather a structured summary of the qualities that participants associated with preferred handheld kitchen tools in everyday use.

Function-related reasons appeared most frequently across the survey responses. Participants repeatedly described their preferred handheld kitchen tools in terms of efficiency, convenience, safety, versatility, reliability, and ease of maintenance. Examples included strong mixing power, peeling efficiency, heat resistance, multifunctionality, anti-stick usability, easy one-handed operation, precision cutting, and effective force transfer. In many cases, participants explained their preference by referring directly to what the tool enabled them to do in everyday cooking tasks, such as saving effort, reducing mess, protecting cookware, or making the task feel easier and safer. These responses show that practical performance was the most explicitly articulated reason for preference across the collected survey materials.

By contrast, form-related preferences appeared more consistently across different examples. Participants repeatedly referred to qualities such as comfortable grip, lightweight structure, manageable size, balance, ease of control, portability, and self-supporting or detachable structures. These comments were not limited to one specific category of tool, but appeared across knives, peelers, tongs, scissors, lemon squeezers, and other objects. Several responses emphasized reduced strain during use, better control for smaller hands, or easier handling during repeated everyday tasks. This suggests that participants often valued physical form not only for how it supported a specific function, but also for how it shaped bodily comfort and confidence across different tools and contexts.

Aesthetic considerations appeared less frequently than function or form, but they were still present in a meaningful way. When aesthetics were mentioned, they were usually discussed alongside other qualities rather than as independent reasons on their own. Participants referred to color, pleasant appearance, clean presentation, minimal visual character, or playful biomorphic form. In some cases, visual appeal was directly tied to usability or emotional preference, such as valuing a tool because it looked nice, felt visually cleaner on the table, or expressed a distinctive character through its form. These findings suggest that aesthetic preference was not usually the most explicit or dominant reason for choosing a tool, but it still contributed to how participants described a desirable kitchen object.

In addition to these three descriptive categories, material-related qualities emerged repeatedly across responses during later review. Although material was not initially coded as a separate category, participants frequently referred to features such as heat insulation, protection of non-stick cookware, texture, durability, ease of cleaning, and surface behavior during use. Examples included silicone tools valued for protecting cookware and providing heat resistance, wooden or metal elements appreciated for durability or tactile quality, and handles or surfaces described as easier to grip, clean, or maintain. These comments suggest that participants often noticed material not as an isolated technical specification, but as something closely connected to comfort, protection, maintenance, and everyday bodily interaction with the tool.

Another notable pattern across the survey is that many preferred tools were valued not for novelty, but for familiarity, practicality, and effort reduction. A number of responses described tools as dependable, straightforward, or "honest" in the way they performed ordinary kitchen tasks. Participants appreciated tools that reduced mess, protected cookware, saved effort, felt intuitive in hand, or simplified repeated actions. These descriptions indicate that preferred handheld kitchen tools were often appreciated less for technological complexity and more for how naturally they fit into everyday routines.

Across the survey as a whole, the findings show that users' preferences for handheld kitchen tools were shaped by a combination of tool-specific functional usefulness, recurring form-related comfort and control, less frequent but still meaningful aesthetic qualities, and repeatedly mentioned material-related characteristics. In this sense, the survey provides a broader contextual picture of what users notice and value in handheld kitchen tools beyond the specific prototype examined in user testing.

6.2 Design Insights

While Section 6.1 presented the direct findings generated through the analysis described in Section 3.2, the present section translates those findings into design insights for future iteration. In relation to the knowledge loop discussed in Section 2.2.2, this stage corresponds to the point at which feedback gathered from end users is reorganized into a form of data representation that can inform the work of the information user, in this case the designer. Within the present study, this process can be understood as part of the second cycle of the loop: not yet a new round of prototype development, but the interpretive stage through which analyzed findings are transformed into guidance for the next iteration. To maintain a clear correspondence with the previous section, the user testing insights are organized according to the same six thematic groups used in Section 6.1.1, while the survey insights follow the main directions identified in Section 6.1.2.

6.2.1 Insights Transferred From User Testing

The following insights are derived from the findings presented in Section 6.1.1 and are organized according to the same six thematic groups. Unlike the findings themselves, which report patterns observed in the analyzed data, these insights translate those patterns into possible directions for future refinement of the prototype. In this sense, the section focuses not on what participants did or said directly, but on what those responses suggest for the next iteration of development.

Ergonomics and Physical Comfort.

The findings suggest that the overall ergonomic direction of the device should be retained, but that ergonomic refinement in the next iteration should extend beyond handle comfort alone. Since several participants described the device as lightweight and manageable, and some instinctively positioned their thumb on the main button, the basic scale and grip relationship appear to be moving in the right direction. However, the repeated misuse caused by the close fit between the measurement cup and the sample container indicates that ergonomic clarity must also include the bodily readability of component roles. In the next iteration, these two parts should be made less visually and physically “fit” to one another so that users are less likely to treat them as one assembled testing unit. In addition, the left-handed-friendly response to the current locking direction suggests a meaningful inclusive design direction. Rather than treating one locking orientation as universally correct, the lower handle could be developed as an interchangeable accessory with left- and right-handed versions, allowing users to select the version that better matches their own motor habits and handedness. In this sense, ergonomic refinement should address not only comfort, but also user diversity in physical use patterns.

Device Operation.

The findings related to device operation indicate that the single-button logic itself should remain minimal, but that the next iteration should provide clearer guidance about what each visible part of the device is for and how the basic sequence of use should begin. Since several participants initially interpreted the device through familiar analogies such as a flashlight, speaker, or complete self-contained unit, the prototype would benefit from a more explicit layer of instructional support during first-time use. One direction for refinement would be to develop optional multimodal instructions that clarify the basic operational logic of the device, including part recognition, button function, orientation, and attachment procedure. Because such guidance does not necessarily need to be permanently placed on the physical body, it could be implemented through the app as an optional instructional layer, combining text, icon, animation, and possibly other modalities to support different user preferences. The purpose of this addition would not be to make the device dependent on instructions for every use, but to reduce confusion during first encounters and to clarify the relationship between the device's parts, their functions, and the intended direction of operation.

Sample Preparation Process

The findings from sample preparation indicate that this should remain the highest-priority area for refinement in the next iteration. The repeated uncertainty around sample amount, sample transfer, attachment after filling, and risk of spillage suggests that the current preparation process requires too much precision and caution. The measurement cup in particular should be reconsidered as a more usable and familiar preparation tool. Based on participant feedback, one direction would be to make the measurement cup larger and more stable to hold, while also adding clearer volume markings that align more closely with users' prior experience of measuring liquids. At the same time, the opening of the sample container could be widened so that pouring from larger dairy packages becomes easier and less stressful. These two changes would work together with the earlier ergonomic insight that the measurement cup and sample container should be less easily mistaken for one another. In other words, the next iteration should aim not only to improve quantitative accuracy, but to make the entire preparation stage more physically forgiving, visually understandable, and compatible with everyday kitchen habits.

App Interaction

The findings from app interaction suggest that the next iteration should continue to use the application as a supportive contextual layer, but should better accommodate different levels of user attention to text. Since some participants relied on textual information while others largely ignored it, the interface should not assume that all users will process explanatory text in the same way. A stronger next step would therefore be to make textual information more selectively accessible. Key operational actions, such as selecting the testing target, should remain highly visible and visually emphasized, while more detailed information about the selected product or testing target could be presented as an optional layer that users may expand only when needed. In this way, users who want more contextual detail can choose to view it, while those who prefer a faster and more visually direct flow are not burdened by unnecessary reading. The broader implication is that future app refinement should support multiple attention styles through layered information hierarchy rather than through one uniform presentation strategy.

Feedback Interpretation

The findings related to feedback interpretation indicate that the current multimodal feedback structure is already effective, but they also suggest that future refinement should make this system more adjustable to individual user preference. Since participants responded differently to sound and vibration, and one participant explicitly described the vibration as too strong while others found non-visual feedback useful, the next iteration could treat multimodal feedback not only as a fixed output system, but also as a user-selectable one. A particularly relevant direction would be to allow users to choose, through the app, which feedback channels they want the device to present during use. For example, users could keep LED feedback active while muting sound or vibration, or adjust the intensity of vibration and auditory output according to their own preference and sensory comfort. This would allow the system to maintain the benefits of multimodal communication without assuming that all users want the same balance of modalities. In this sense, the next iteration could move from multimodal feedback as a universal package toward multimodal feedback as a configurable inclusive feature.

User Expectations, Perceptions, and Suggestions

The final thematic group suggests that the next iteration should take prior expectations and first impressions seriously as part of the design process. Participants repeatedly interpreted the prototype through familiar domestic objects and product conventions, and these analogies sometimes supported understanding while at other times redirected the interaction in unintended ways. This means that future refinement should be developed with stronger awareness of what existing objects the prototype visually or functionally resembles, and what assumptions those similarities are likely to trigger. At the same time, the repeated comments about learning and practice suggest that the prototype already contains a logic that becomes clearer over time, which is a valuable strength to preserve. The design implication here is therefore twofold: misleading cues should be reduced so that first-time use becomes less confusing, while the learnable structure of the current interaction should remain intact. Participant suggestions should not be adopted one by one without further testing, but they are still valuable because they reveal where users most strongly felt the need for reassurance, simplification, or clearer guidance.

Taken together, these user testing insights suggest that the next iteration should focus on redistributing complexity across the interaction flow rather than changing the overall concept of the system. The stronger parts of the current prototype, particularly feedback interpretation and the basic app structure, can be retained and further strengthened, while the more demanding parts, especially physical preparation, component distinction, and first-time device interpretation, should be simplified and clarified. In this sense, the next iteration would not need to abandon the current system logic, but should make that logic easier to perceive, easier to configure, and easier to perform in practice.

6.2.2 Insights Transferred From Survey

The survey suggests that future refinement should continue to position the prototype as a practical kitchen tool rather than as a lab-like testing device. Across the collected responses, participants repeatedly valued handheld tools for reducing effort, supporting specific tasks effectively, and fitting naturally into ordinary cooking routines. For the next iteration of this project, this implies that the prototype should communicate its usefulness through everyday task support, clarity of purpose, and a stronger sense of belonging within domestic kitchen settings. In this way, the system can feel less formal and intimidating, and more compatible with the relaxed, routine context in which dairy checking is likely to occur. This direction also aligns with the original decision to frame user testing within a kitchen-based scenario.

The survey also indicates that future refinement should continue to prioritize ergonomic form and bodily manageability. Preferred kitchen tools were often valued for their comfortable grip, manageable size, ease of control, and reduced physical strain. This suggests that form should remain a central design variable in the next iteration, not simply as an outer shell, but as a key contributor to confidence, controllability, and long-term usability. For this project, the implication is that future prototype refinement should continue to support stable handling, comfortable operation, and a sense of bodily ease in use, especially given that users often understand the quality of a handheld tool through how it feels in the hand rather than through technical performance alone.

Although aesthetic reasons appeared less frequently in the survey responses than functional or form-related reasons, they still suggest an important direction for future refinement. In the responses, aesthetics was not limited to decorative appearance alone, but was often connected to how an object felt in the kitchen environment, how approachable or pleasant it appeared, and how naturally it fit into domestic life. As discussed in the original interpretation of these survey results, this opens a broader inclusive design question: aesthetic design may also shape how visible or discreet a user's specific need becomes in everyday situations. Drawing on Pullin's argument that "Whether a person decides to display or conceal her disability–and the designs of devices and prostheses should be enabling a choice of such expression–perhaps there is a separate issue of feeling comfortable in private." (Pullin, 2009, pp. 235). In this sense, aesthetics becomes relevant not only to preference, but also to discretion, self-expression, and comfort in daily use.

Material-related considerations also emerge as a distinct insight from the survey, even though material was not initially treated as one of the three formal categories in the first round of organization. Across responses, participants repeatedly referred to qualities such as heat resistance, durability, texture, easy cleaning, waterproofing, non-slip handling, and cookware protection. As reflected in the original interpretation of these survey results, this suggests that material should not be treated merely as a supporting attribute, but as an integral part of how usability, safety, and comfort are experienced. For the next iteration of this project, material selection should therefore be explored more deliberately as a design variable that shapes bodily confidence and perceived reliability during use. This is especially relevant because the current prototype remains relatively early in its material exploration, meaning that future refinement could benefit from more intentional investigation into how different materials influence grip, maintenance, protection, and overall user experience.

A further insight from the survey is that users often valued tools that felt dependable, straightforward, and easy to integrate into repeated routines. Many of the preferred objects were not described as highly technological or visually dramatic, but as ordinary tools that performed well and fit naturally into everyday kitchen life. This suggests that future iterations of the prototype should avoid becoming unnecessarily complex, overly expressive as a piece of technology, or too far removed from familiar kitchen-tool expectations. Instead, refinement should continue to move toward a system that feels practically legible and domestically appropriate, so that adoption is supported through familiarity as well as function. In this sense, familiarity should not be treated as the opposite of innovation, but as a condition that can help a new design become easier to trust and incorporate into daily practice.

Taken together, the survey insights suggest that the next iteration should continue to develop toward a system that is practically useful, physically supportive, visually and socially considerate, materially reassuring, and easy to incorporate into everyday domestic routines. Compared with the user testing insights, which pointed more directly to interaction-specific difficulties within the prototype, the survey insights provide a broader frame for the kinds of qualities the system should continue to move toward as it develops. In this way, the survey helps situate future refinement not only in relation to the current prototype, but also in relation to wider expectations surrounding handheld kitchen tools and everyday use.

6.3 Next Steps: Recommendations List

Building on the design insights discussed in Section 6.2, this section summarizes a set of recommendations for the next iteration of the prototype. These recommendations do not represent finalized design decisions but rather identify the main directions that should guide future refinement based on the findings of the present study.

6.3.1 Recommendations for Physical Components and Handling

1. Retain the current ergonomic direction while clarifying the role of the measurement cup within the preparation process

The overall ergonomic scale, grip relationship, and general handling direction of the current device could be retained, as they supported manageable use and basic physical comfort during the testing stage. However, the next iteration could make the role of the measurement cup more explicit as a temporary preparation tool for measuring and transferring the sample, rather than as a component that remains attached during testing. Since several participants interpreted the measurement cup as something that could be placed on the sample cup and inserted together, future refinement could strengthen the distinction between preparation tools and testing components through differences in form, size, colour, surface texture, or storage position. At the same time, the sample cup itself could include clearer visual and tactile guidance to indicate that it is the part intended to connect with the handle. For example, visual alignment marks, directional icons, tactile notches, or Braille labels on the device surface could help users identify the correct connection point and understand the intended assembly sequence without relying only on written instructions.

2. Prioritize redesign of the sample preparation process while preserving its role within the overall system logic

The preparation stage could be treated as a key area for refinement in the next iteration, since participant feedback suggests that this part of the interaction required a high level of precision, caution, and manual control. While separating preparation from testing may still offer value by keeping the sensing process more controlled, the current process also introduced concerns around pouring, spilling, and aligning a small amount of liquid within the sample cup. Future prototype development could therefore explore a more physically forgiving preparation process, including, for example, a wider sample cup opening, clearer volume markings, and a more stable measuring tool. The next iteration could also re-examine whether a fixed sample cup is necessary in its current form. If the sample could be prepared or presented to the device through a simpler container, disposable liner, or alternative contact/non-contact structure, the overall flow might become easier to understand and more user-friendly in everyday kitchen use.

3. Preserve the current physical handling strengths while improving adaptability for diverse handedness and motor habits

The present prototype shows promising ergonomic potential in relation to manageable grip, bodily control, and overall handling comfort. These qualities could be carried forward in the next iteration, while the locking mechanism could be further developed to accommodate different handedness and motor habits. Since the current locking direction received positive feedback from a left-handed participant (p4), future refinement could avoid treating one twisting direction as universally suitable. One possible exploration in locking-direction would be to develop the lower handle as an optional or interchangeable module, allowing users to choose a version with a locking direction that better matches their habitual hand use. This would allow the system to remain conceptually consistent while offering more flexibility in how different users physically operate the device.

4. Retain material as part of the core interaction concept and investigate it more deliberately as a design variable

Material qualities could be treated as an important part of the interaction experience, rather than only as a final surface or finishing decision. Survey responses (see section 6.1.2) suggest that users may associate material with usability, safety, cleanliness, comfort, and experience in everyday kitchen use. Since the current prototype remained at an early stage of material development, a useful next step could be to conduct a series of material comparisons before producing the next physical prototype. This comparison could examine surface texture, grip security, moisture resistance, cleanability, food-related safety handling, and durability in domestic kitchen conditions. Based on these comparisons, the next iteration could then be developed using the materials that best fit the intended use context, rather than relying on prototype materials selected mainly for fabrication convenience. This would allow material decisions to become part of the design logic of the device, especially in relation to comfort, hygiene, handling confidence, and repeated everyday use.

6.3.2 Recommendations for the App and Digital Support

5. Retain the app's role as a contextual support layer while refining its information hierarchy

The app could continue to function as an important contextual layer of the system, particularly because dairy products may differ across product types, brands, formulations, and storage conditions. Since these differences could affect how spoilage-related signals are interpreted, the app offers a more flexible place to manage and update product-specific information than the physical device itself. In this system, the app also acts as an input interface: users select the relevant dairy sample category in the app, and this selection provides the device with the corresponding testing context. This arrangement could help keep the physical device simpler, while allowing the digital layer to support more detailed and adaptable detection criteria. At the interface level, future refinement could also respond to the finding that participants engaged with text in different ways. Some users relied on textual content, while others focused mainly on interface changes and key visual cues. Therefore, primary actions, selected sample type, testing status, and result feedback could remain highly visible, while more detailed explanations, product-specific notes, or guidance could be placed in optional expandable layers for users who need additional context.

6. Maintain the minimal device logic while using the app to support clearer first-time interpretation

The single-button control could remain part of the system because it keeps the physical device simple and avoids adding unnecessary operational complexity. At the same time, future refinement could provide more support for first-time users when they interpret the device's parts, orientation, and sequence of use. Since some participants initially understood the device through familiar object associations, such as a flashlight, speaker, or complete self-contained unit, the app could offer optional onboarding or step-by-step guidance to clarify what each component does and how the user moves from preparation to testing. This guidance could include short text, icons, sequential images, simple animation, or multimodal cues. Rather than making the device dependent on instructions every time, the app could support the first few uses and help users build a clearer mental model of the system.

7. Preserve the current multimodal feedback logic while making it more configurable through the app

The existing multimodal feedback structure could be carried forward as one of the stronger aspects of the prototype, since participants generally understood the system states more clearly when feedback was communicated through multiple sensory channels. However, participant responses to sound and vibration were not identical, which suggests that multimodal feedback may work better as a flexible setting rather than as one fixed output package. Future refinement could therefore explore app-based customization options, allowing users to turn specific feedback channels on or off, select preferred combinations of light, sound, and vibration, or adjust the intensity of sound and vibration. This direction also aligns with the feature requirements identified in *Appendix L:Alternative Approaches and Application Feature Requirements*, where customizable feedback was previously listed as an Ideal-priority feature. In a later iteration, this feature could be tested as part of the app's accessibility and personalization functions, allowing the system to support different sensory preferences, environmental contexts, and accessibility needs through flexibility rather than uniformity.

6.3.3 Recommendations for Overall System Development

8. Reduce misleading object associations through form and cue testing while preserving learnability

Future refinement could examine which visual, tactile, and auditory cues lead users to associate the prototype with familiar objects such as flashlights or speakers. Rather than removing familiarity entirely, the next iteration could identify which associations support intuitive understanding and which create confusion about the device's function, orientation, or assembly sequence. For example, flashlight-like interpretations may be influenced by the cylindrical handheld form and the forward-facing light cue (from p7). This could be addressed by repositioning the light output, softening the directional emphasis of the front end, or strengthening visible cues that indicate the testing connection point rather than a beam-emitting front. In contrast, speaker-like interpretations appeared to be influenced (from p3) less by the overall concept and more by the temporary 3D-printed button surface, whose printed texture resembled a speaker grille. This issue may naturally diminish in later iterations when the prototype is redeveloped using alternative materials and more resolved component finishes. These aspects could be tested through quick first-use trials, asking participants how they interpret the device, where they expect interaction points to be, and what function they assume each part performs.

9. Continue to develop the prototype as a practical domestic kitchen tool rather than a lab-like device

The system could continue to be developed within a domestic kitchen context, with future refinement drawing on survey responses and potentially broader survey data to better understand how users expect a handheld kitchen tool to look, feel, and operate. This could include collecting feedback on form, size, material, cleaning expectations, storage, and the perceived difficulty of the interaction flow. In particular, preparation steps that feel overly precise or technically demanding could make the device seem more like a lab instrument than an everyday kitchen aid. This may not only increase hesitation or anxiety during use but also exclude users who are less confident with technical tools, have limited experience with formal testing procedures, or prefer simpler everyday interactions. Since this would conflict with the inclusive design direction of the project, later iterations could explore forms and operation sequences that feel more familiar, relaxed, and compatible with ordinary food preparation habits. This direction could help the prototype communicate everyday usefulness rather than technical specialization, allowing it to fit more naturally into routine kitchen decision-making.

10. Treat aesthetics as part of approachability, domestic fit, and user discretion

Aesthetic refinement could be understood as more than making the device visually attractive, colourful, or decorative. In later iterations, visual and tactile qualities could be explored in relation to how approachable, comfortable, and domestic the device feels in everyday use. At the same time, the device's appearance could also give users more control over how visible their needs are to others. For some users, a clearly recognizable assistive or safety-related device may feel validating and useful; for others, a more discreet kitchen-tool appearance may better support privacy and everyday confidence. Future refinement could therefore compare different visual directions, from more expressive designs to more understated domestic forms, to explore how aesthetics can support both personal expression and discretion.

11. Use familiarity to support adoption and repeated everyday use

Future refinement could draw more deliberately on familiar kitchen-tool conventions to make the system easier to understand, accept, and incorporate into routine practice. This may include referencing familiar gestures, such as scooping, pouring, twisting, rinsing, or storing; familiar object relationships, such as cups, lids, handles, or small countertop tools; and familiar maintenance expectations, such as easy cleaning and simple storage. In this sense, familiarity does not need to limit innovation. Instead, it could become a strategy for lowering the learning barrier and helping users feel that the device belongs within ordinary food preparation. Later iterations could therefore test which familiar cues support confidence and repeated use, while avoiding cues that create incorrect assumptions about the device's function.

Overall, these recommendations suggest that the next iteration should focus not on changing the core concept of the system, but on refining how that concept is delivered practically. The stronger aspects of the current prototype can be retained and further developed, while the more demanding parts of the interaction should be made easier to learn, perceive, configure, and perform in everyday use.

7.0 Limitations

Several limitations should be acknowledged in relation to the scope, methods, and stage of development of this study.

First, the study did not aim to validate actual dairy spoilage detection accuracy. Although the prototype incorporated a functional simulation system, this system relied on a controllable proxy rather than scientifically validated spoilage sensing. This was a deliberate scope decision made in order to focus the research on interaction design, usability, and user interpretation rather than on engineering-level sensor development or food-science validation. As a result, the findings of this study should not be understood as evidence of technical detection accuracy, but rather as insights into how users engage with and make sense of the proposed interaction system.

Second, the range of direct user perspectives in the in-person testing remained limited. The testing group was relatively small and recruited mainly through a university context, with only a smaller number of participants reached through personal networking channels. This means that the in-person findings were shaped primarily by a relatively narrow participant pool and do not represent the full range of potential users relevant to the project. Although the online survey helped broaden the overall picture by introducing a wider set of perspectives, it did not function as a substitute for direct prototype testing across a more diverse user population.

Third, the study concludes after the first full cycle of prototype development, user testing, and analysis, rather than extending into a second prototype and evaluated iteration. In this sense, the design insights and recommendations generated in this research identify directions for future refinement, but they have not yet been tested through a subsequent prototype. This limits the extent to which the study can claim how effectively the identified issues would be resolved in practice through later design iterations.

Finally, the current prototype remained constrained by the material and structural conditions of early-stage prototyping. Some aspects of the user experience may therefore have been influenced not only by the intended interaction logic, but also by the unfinished qualities of the prototype itself, including material choices, fabrication limitations, and provisional structural solutions. For this reason, some of the usability issues identified in the study should be interpreted with an awareness that they emerged within an early prototype condition rather than from a fully refined product.

8.0 Conclusion

This study explored the design of a handheld system intended to support dairy-related decision-making through an interaction-focused and inclusive design approach. Beginning from the unmet needs of individuals with olfactory impairments, the project examined how a system could reduce reliance on smell while remaining relevant to broader everyday kitchen use. Rather than treating the problem mainly as one of sensing accuracy, the study focused on how such a system could be understood, operated, and interpreted in practice. To explore this, the research developed a prototype consisting of a handheld device, sample-related components, functional simulation, and a supporting mobile application, and examined these elements as one integrated interaction system.

The findings show that the prototype did not perform uniformly across all stages of interaction. The greatest concentration of usability issues emerged during sample preparation where participants encountered uncertainty about sample amount, component roles, and attachment direction. By contrast, app-based target selection and multimodal result interpretation were more consistently understood, with coordinated feedback across the device and app becoming one of the strongest parts of the system. The online survey further broadened this picture by showing that preferred handheld kitchen tools were often valued not only for practical usefulness, but also for physically supportive form, material qualities, and their fit within everyday domestic routines. Together, these results suggest that future refinement should focus less on changing the overall concept of the system and more on redistributing complexity across the interaction flow, especially by simplifying preparation for sampling. Overall, this study does not claim to have resolved the problem of dairy spoilage assessment for users who cannot rely on smell. Instead, it demonstrates one way of approaching that problem through an iterative, inclusive, and interaction-focused design process. By developing a prototype, examining how users engage with it, and translating the resulting findings into directions for future refinement, the project establishes a foundation for continued development. In this sense, its main contribution lies not in presenting a finalized solution, but in showing how a design that begins from a specific unmet need can be progressively shaped toward broader usability and everyday applicability.

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Appendix A: In-person Consent Form

OCAD UNIVERSITY

Consent Form

Date: 2025/10/25
Project Title: Inclusive Design for Dairy Spoilage Detection: Supporting Users with Olfactory Impairments

Principal Investigator:
Student: Jiaxin Zou
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Faculty Supervisor:
Nancy Snow
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PURPOSE

- This study is part of a graduate research project in the Inclusive Design program at OCAD University.
- The goal is to explore how people's lived experiences and daily habits can help improve the accessibility and usability of a handheld food safety device that detects spoilage in dairy products. By participating, you will help the researcher understand how individuals with different ways of using kitchen tools interact with the prototype.
- Your feedback will inform how the form of the handheld device can be refined to easier and more inclusive for a wider range of people.
- To join, you need to be able to communicate in English/Mandarin/Japanese.
- This research is conducted by Jiaxin Zou, a graduate student, as part of a Major Research Project (MRP) under the supervision of Nancy Snow. It is not for commercial purposes and has no external funding.

WHAT'S INVOLVED

As a participant, you will be asked to take part in a short usability testing session to help evaluate and improve a prototype of a handheld food safety device designed to detect spoilage in dairy products. Each session will take place in a classroom or studio space at OCAD University.
During **testing**, you will try using the prototype and provide feedback about its usability, comfort, and clarity. In the **interview**, you will be asked to share your thoughts about your experience. The researcher will not use audio or video recording; instead, written notes will be taken to capture general comments and observations.

Participation will take approximately 30 minutes per session. Each session will involve **hands-on testing (about 20-25 minutes)** and a short **follow-up interview (about 5-10 minutes)**. Participants may be invited to return for later rounds to provide additional feedback on the updated design, but participation in multiple sessions is entirely voluntary.

- Your email will only be used for scheduling and communication.
- No personal, medical, or demographic data will be collected other than what is needed to confirm eligibility (age, language, and residency in the Greater Toronto Area).

POTENTIAL BENEFITS

- By testing the food safety device and sharing their thoughts, participants will help the researcher understand what parts are easy to use and what parts could be improved. Their comments will guide how the next version of the device is made.
- Participants may also learn how design research works and how their feedback can help create better tools for people with different needs or abilities.
- Participants can ask to receive a short summary at the end of the project that explains how their ideas helped improve the design.
- Their time and opinions are highly valued, and their participation will help create safer, more accessible tools that can be used by everyone in daily life.

POTENTIAL RISKS

- This study involves no known or anticipated risks beyond those encountered in everyday activities. Participants will simply handle and interact with a handheld prototype for a short period and share their opinions. If at any time a participant wishes to stop or withdraw from an activity they may do so by letting the reviewer know that no longer wish to participate.

CONFIDENTIALITY

- All information collected during this project will be kept strictly confidential. Participants will not be identified by name in any notes, reports, or publications. Only the researcher and supervisor (Jiaxin Zou and Nancy Snow) will have access to the raw data. Participants will be referred to by pseudonyms or general descriptors (e.g., "Participant 1") in all materials. Email addresses will be used solely for scheduling purposes and deleted after the study is complete. All identifiable information will be destroyed once the data have been anonymized and summarized.
- **Audio-recording**: With participants' consent, the full testing session will be audio-recorded to ensure that all responses are accurately understood and transcribed. The recording will help the researcher, who is not a native English speaker, to review participants' comments carefully and avoid misinterpretation.
- Because the researcher will be present during the in-person sessions to facilitate testing, participation cannot be fully anonymous. The researcher may be able to recognize participants during the session; however, all information observed or recorded will be treated as confidential and handled in accordance with research ethics requirements.
- Participants will not be asked to review or edit the transcripts because the recording is used only to ensure accuracy and will not be quoted directly. The audio files and transcripts will be used only for analysis by the researcher and will be permanently deleted once the Major Research Paper is published.

DATA COLLECTION AND STORAGE

- All data collected during this project will be stored securely on a password-protected personal computer accessible only to the researcher. Data will not be shared with any third parties and will be permanently deleted after analysis and reporting are complete.
- All collected data will be deleted immediately after the publication of the Major Research Project (MRP). This ensures that participants' personal information remains fully protected and that no identifiable data are retained beyond the project's conclusion.
- Access to this data will be restricted to Jiaxin Zou and Nancy Snow.

INCENTIVES FOR PARTICIPATION

- Participants will receive a **$5 CAD coffee gift card** as a token of appreciation even if they choose not to complete the full session.
- If a participant decides to withdraw their data after completing the session, their data will be deleted, but they will still receive the gift card.
- These incentives are intended to acknowledge participants' time and contribution. Participation in this study is entirely voluntary, and declining or withdrawing from the study will not result in any penalties.

VOLUNTARY PARTICIPATION

- Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study.
- Further, you may request withdrawal of your data prior to data analysis and you may do so without any penalty or loss of benefits to which you are entitled. Your choice of whether or not to participate will not influence your future relations with OCAD University [and/or other institutions/partners of the research] or the investigators Jiaxin Zou and Nancy Snow involved in the research.
- To withdraw from this study, let the student researcher know at any point during the study or you may contact *Jiaxin Zou* by email at jiaxin.zou@ocadu.ca
- To withdraw your data from the study, please contact *Jiaxin Zou* by email at Jiaxin.zou@ocadu.ca no later than 10 days after the completion of participation. Upon receiving a withdrawal request, all notes and records associated with the participant will be permanently deleted from the researcher's password-protected device. Any handwritten notes will be securely shredded. Once removed, no copies of the data will be retained, and the information will not be included in any analysis or publication related to this study.

PUBLICATION OF RESULTS (checkable)

- Results of this study may be published in the researcher's Major Research Project (MRP) and may also be presented in academic reports, design exhibitions, or conferences related to inclusive design. In any publication, data will be presented in aggregate forms. Quotations from interviews or surveys will not be attributed to you without your permission.

POSSIBLE FOLLOW-UP CONTACT FOR DESIGN INTERATION (checkable)

- Because this study follows an inclusive design process that involves multiple iterations, this study **may** involve future design updates and additional testing sessions. After your participation in the current session, you **may be contacted again by email** to invite you to take part in another similar session by checking "yes" to agree with a reconnect through email below.
- This follow-up would allow the researcher to gather your feedback on an improved version of the prototype and better understand whether the changes make it easier to use.
- Agreeing to be contacted does **not** mean you are required to join future sessions, participation in any additional testing will remain completely voluntary.

CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please ask. If you have questions later about the research, you may contact the Principal Investigator Jiaxin Zou or the Faculty Supervisor Nancy Snow using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University [#7031].

If you have questions regarding your rights as a participant in this study please contact:
Research Ethics Board c/o Office of the Vice President, Research and Innovation
OCAD University
100 McCaul Street
Toronto, M5T1W1
416 977 6000 x4368
research@ocadu.ca

AGREEMENT

Audio recording

☐ *I agree to be audio-recorded for the purposes of this study. I understand how these recordings will be stored and destroyed.*

☐ *I do not agree to be recorded for the purposes of this study.*

Possible follow-up contact for design iteration

☐ *Yes, I agree to be contacted for possible follow-up participation via (your email address)*

____

☐ *No, I do not wish to be connected again after this session.*

I agree to participate in this study described above. I have made this decision based on the information I have read in the Information-Consent Letter. I have had the opportunity to receive any additional details I wanted about the study and understand that I may ask questions in the future. I understand that I may withdraw this consent at any time.

Name: ______________________________

Signature: ______________________________ Date: ______________________________

Thank you for your assistance in this project. Please keep a copy of this form for your records.

同意书

日期：2025 年 10 月 25 日 项目名称：乳制品变质检测的包容性设计：支持嗅觉障碍用户

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目的

- 这项研究是安大略艺术设计大学包容性设计项目研究生研究项目的一部分。
- 本次研究旨在探索人们的生活经验和日常习惯如何帮助提升一款用于检测乳制品变质的手持式食品安全设备的易用性和可访问性。您的参与将有助于研究人员了解不同厨房用具使用习惯的个体如何与原型设备互动。
- 您的反馈将有助于改进手持设备的外形，使其更易于使用，更适合更广泛的人群。
- 要加入，你需要能够用英语/普通话/日语交流。
- 这项研究由研究生邹佳欣在南希・斯诺（Nancy Snow）的指导下，作为重大研究项目（MRP）的一部分进行。本研究不用于商业用途，亦未获得任何外部资助。

涉及的内容

作为参与者，您将被邀请参加一次简短的可用性测试，以帮助评估和改进一款用于检测乳制品变质的手持式食品安全设备原型。每次测试都将在 OCAD 大学的教室或工作室进行。测试期间，您将试用该原型，并就其可用性、舒适度和清晰度提供反馈。在访谈中，您将被要求分享您的使用体验。研究人员不会使用音频或视频录制；而是会做书面笔记来记录您的总体意见和观察结果。

每次参与大约需要 30 分钟。每次参与都将包含实践环节。
测试（约 20-25 分钟）和简短的后续访谈（约 5-10 分钟）。参与者
可能会被邀请参加后续几轮，对更新后的设计提供更多反馈，但参加多轮会议完全是自愿的。

- 您的邮箱地址仅用于日程安排和沟通。

除了确认资格所需的信息（年龄、语言和大多伦多地区的居住情况）外，不会收集任何个人、医疗或人口统计数据。

潜在益处

- 通过测试食品安全装置并分享他们的想法，参与者将帮助研究人员了解哪些部分易于使用，哪些部分可以改进。
  他们的意见将指导下一代设备的研发。
- 参与者还可以了解设计研究是如何进行的，以及他们的反馈如何帮助为有不同需求或能力的人创造更好的工具。
- 项目结束后，参与者可以要求获得一份简短的总结报告，说明他们的想法如何帮助改进设计。
- 他们的时间和意见非常宝贵，他们的参与将有助于创造更安全、更易于使用的工具，供每个人在日常生活中使用。

潜在风险

- 本研究不涉及除日常活动中可能遇到的风险之外的任何已知或预期风险。参与者只需在短时间内操作和使用手持原型机并分享他们的意见。如果参与者希望随时停止或退出活动，只需告知评审员即可。

保密性

- 本项目收集的所有信息将严格保密。所有记录、报告和出版物中均不会提及参与者的姓名。只有研究员和导师（邹嘉欣和南希・斯诺）可以访问原始数据。所有材料中都将使用化名或通用描述符（例如，“参与者 1”）指代参与者。电子邮件地址仅用于安排日程，研究结束后将立即删除。数据匿名化和汇总后，所有可识别信息将被销毁。

- 录音：经参与者同意，整个测试过程将被录音。
  确保所有回答都被准确理解并转录。录音将有助于
  研究人员并非以英语为母语，因此需要仔细审阅参与者的评论，避免误解。

- 由于研究人员将在现场协助测试，因此参与者无法完全匿名。研究人员可能会在测试过程中认出参与者；但是，所有观察或记录的信息都将严格保密，并按照研究伦理要求进行处理。

- 参与者无需审阅或编辑文字稿，因为录音仅用于确保准确性，不会被直接引用。音频文件和文字稿仅供研究人员分析之用，并在主要研究论文发表后永久删除。

数据收集与存储

本项目收集的所有数据将安全地存储在只有研究人员才能访问的、设有密码保护的个人电脑上。数据不会与任何第三方共享，并在分析和报告完成后永久删除。

- 重大研究项目（MRP）发布后，所有收集的数据将立即删除。这确保了参与者的个人信息得到充分保护，并且项目结束后不会保留任何可识别身份的数据。

- 只有邹嘉欣和南希・斯诺才能访问这些数据。

参与激励措施

- 即使参与者选择不完成整个课程，他们也将获得一张价值 5 加元的咖啡礼品卡作为感谢。

- 如果参与者在完成会议后决定撤回其数据，他们的数据将被删除，但他们仍将收到礼品卡。

- 这些奖励旨在表彰参与者的时间和贡献。
  参与本研究完全出于自愿，拒绝或退出研究不会受到任何惩罚。

自愿参与

- 参与本研究纯属自愿。如果您愿意，您可以拒绝回答任何问题或参与本研究的任何部分。

- 此外，您可以在数据分析前要求撤回您的数据，且不会因此受到任何处罚或损失您应享有的任何权益。您是否参与本研究不会影响您与安大略艺术设计学院（OCAD University）[和/或其他研究机构/合作伙伴]或参与本研究的邹嘉欣（Jiaxin Zou）和南希・斯诺（Nancy Snow）两位研究人员的未来关系。

- 如需退出本研究，请在研究期间随时告知学生研究员，或通过电子邮件联系邹嘉欣（jiaxin.zou@ocadu.ca）。
- 如需从研究中撤回您的数据，请在参与结束后 10 天内通过电子邮件联系邹嘉欣（Jiaxin.zou@ocadu.ca）。收到撤回请求后，研究人员将从其受密码保护的设备中永久删除与该参与者相关的所有笔记和记录。任何手写笔记都将被安全销毁。数据删除后，我们将不会保留任何副本，并且这些信息不会用于与本研究相关的任何分析或出版物中。

结果公布（可核查）

- 本研究结果可能会发表在研究者的主要研究项目（MRP）中，并且
  也可能在与包容性设计相关的学术报告、设计展览或会议上发表。所有出版物中的数据均以汇总形式呈现。未经您的许可，我们不会引用访谈或调查中的语句。

设计合作后续联系方式（可核实）

- 由于本研究采用包容性设计流程，并经过多次迭代，因此未来可能会进行设计更新和额外的测试。在您参与本次测试后，我们可能会再次通过电子邮件联系您，邀请您参加另一次类似的测试。请在下方勾选“是”以同意通过电子邮件再次与您联系。

- 这项后续工作将使研究人员能够收集您对改进版原型的反馈，并更好地了解这些更改是否使其更容易使用。
- 同意接受联系并不意味着您必须参加未来的测试，参加任何额外的测试都将完全出于自愿。

联系信息和道德审查

如果您对本研究有任何疑问或需要更多信息，请随时提出。如果您之后对研究有任何疑问，可以使用上述联系方式联系首席研究员邹嘉欣或指导教师南希・斯诺。本研究已通过安大略艺术设计学院（OCAD University）研究伦理委员会的审查并获得伦理许可（编号：7031)。

如果您对作为本研究参与者的权利有任何疑问，请联系：安大略艺术设计学院（OCAD University）研究伦理委员会，地址：多伦多麦考尔街 100 号，邮编：M5T1W1，电话：416-977-6000 转 4368，邮箱：research@ocadu.ca

协议

录音

☐ 我同意为本研究目的接受录音。我了解这些录音将如何存储和销毁。

☐ 我不同意为本研究的目的而被录音。

可能进行后续联系以进行设计迭代

☐ 是的，我同意通过（您的电子邮件地址）与我联系，以便进行后续的参与活动。

____

☐ 不，本次会话结束后我不想再连接。

我同意参与上述研究。我根据已阅读的信息同意书中的信息做出此决定。我已获得任何我想要了解的关于此研究的额外信息，并理解我将来可能会提出问题。我理解我可以随时撤回此同意。

姓名： ____________________________

签名： 日期： ____________________________ ____________________________

感谢您对此项目的协助。请保留此表格的副本以作记录。

同意書

日付: 2025/10/25 プロジェクト名: 乳製品の腐敗検出のためのインクルーシブデザイン: 嗅覚障害のあるユーザーのサポート

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目的

- この研究は、OCAD 大学のインクルーシブ デザイン プログラムの大学院研究プロジェクトの一部です。
- 目標は、人々の生活経験や日常習慣が、乳製品の腐敗を検知する携帯型食品安全装置のアクセシビリティとユーザビリティをどのように向上させるかを探ることです。ご参加いただくことで、キッチンツールの使い方が異なる人々がプロトタイプとどのように相互作用するかを研究者が理解するお手伝いができます。
- 皆様からのフィードバックは、ハンドヘルド デバイスの形状を改良して、より幅広いユーザーにとってより簡単で包括的なものにするためのヒントとなります。
- 参加するには、英語/中国語/日本語でコミュニケーションできる必要があります。
- この研究は、大学院生のJiaxin Zouが、Nancy Snowの指導の下、主要研究プロジェクト（MRP）の一環として実施しています。商業目的ではなく、外部からの資金提供も受けていません。

何が関係しているか

参加者には、乳製品の腐敗を検知するために設計された携帯型食品安全装置のプロトタイプの評価と改良を支援するため、短いユーザビリティテストセッションへの参加をお願いしています。各セッションは、OCAD 大学の教室またはスタジオスペースで行われます。テスト中は、プロトタイプを実際に使用していただき、その使いやすさ、快適性、明瞭性についてフィードバックを提供していただきます。面接では、使用体験についてのご意見をお聞かせいただきます。調査員は音声録音や動画録画は行いません。代わりに、一般的なコメントや観察事項を記録するためにメモを取ります。

参加には1セッションあたり約 30 分かかります。各セッションでは、実践的な演習を行います。約 20〜25 分のテストと、その後の短いインタビュー（約 5〜10 分）が行われます。参加者は更新されたデザインに関する追加のフィードバックを提供するために、後のラウンドに再度参加するよう依頼される場合がありますが、複数のセッションへの参加は完全に任意です。

・　あなたのメールアドレスはスケジュールと連絡にのみ使用されます。
資格の確認に必要な情報（年齢、言語、グレータートロント地域での居住地）を除き、個人情報、医療情報、人口統計情報は収集されません。

潜在的なメリット

- 参加者は食品安全装置をテストし、感想を共有することで、どの部分が使いやすいのか、どの部分を改善できるのかを研究者が理解するのに役立ちます。
  彼らのコメントは、デバイスの次期バージョンの作成方法の指針となります。
- 参加者は、デザインリサーチの仕組みや、そのフィードバックがさまざまなニーズや能力を持つ人々のためのより優れたツールの作成にどのように役立つかを学ぶこともでき
- 参加者は、プロジェクトの最後に、自分のアイデアがどのようにデザインの改善に役立ったかを説明する短い要約を受け取るように依頼できます。
- 彼らの時間と意見は非常に高く評価されており、彼らの参加は日常生活で誰もが使用できる、より安全でアクセスしやすいツールの作成に役立ちます。

潜在的なリスク

- この研究には、日常的な活動で遭遇するリスクを超える既知または予測されるリスクはありません。参加者は、ハンドヘルドプロトタイプを短時間操作し、インタラクションを行い、意見を共有するだけです。参加者が活動を中止または中止したい場合は、いつでも評価担当者にその旨を通知することで、中止または撤退することができます。

機密保持

- 本プロジェクトで収集されたすべての情報は厳重に機密扱いされます。参加者の氏名は、いかなる記録、報告書、出版物においても特定されることはありません。生データにアクセスできるのは、研究者と指導教員（Jiaxin ZouとNancy Snow）のみです。すべての資料において、参加者は仮名または一般的な名称（例：「参加者 1」）で呼ばれます。メールアドレスはスケジュール管理のみに使用され、研究終了後は削除されます。個人を特定できる情報はすべて、データが匿名化され要約された後、破棄されます。

- 音声録音：参加者の同意を得た上で、テストセッション全体が音声録音されます。
  すべての回答が正確に理解され、書き起こされていることを確認してください。録音は英語を母国語としない研究者は、参加者のコメントを注意深く確認し、誤解を避ける必要があります。
- 研究者は検査を円滑に進めるため、対面セッションに同席するため、参加は完全に匿名ではありません。研究者はセッション中に参加者を認識できる場合がありますが、観察または記録されたすべての情報は機密情報として扱われ、研究倫理要件に従って取り扱われます。
- 参加者はトランスクリプトの確認や編集を求められません。録音は正確性を確認するためにのみ使用され、直接引用されることはありません。音声ファイルとトランスクリプトは研究者による分析にのみ使用され、主要研究論文が発表された時点で完全に削除されます。

データの収集と保存

本プロジェクトで収集されたすべてのデータは、研究者のみがアクセスできるパスワード保護された個人用コンピュータに安全に保管されます。データは第三者と共有されることはありません。また、分析と報告が完了した後、完全に削除されます。

- 収集されたすべてのデータは、主要研究プロジェクト（MRP）の発表後直ちに削除されます。これにより、参加者の個人情報は完全に保護され、個人を特定できるデータはプロジェクト終了後も保持されません。
- このデータへのアクセスは、Jiaxin Zou と Nancy Snow に制限されます。

参加インセンティブ

- 参加者は、セッション全体を完了しない場合でも、感謝の印として 5 カナダドルのコーヒーギフトカードを受け取ります。
- 参加者がセッション終了後にデータを取り消すことにした場合、そのデータは削除されますが、ギフトカードは引き続き受け取れます。
- これらのインセンティブは、参加者の時間と貢献を認めることを目的としています。この研究への参加は完全に任意であり、研究への参加を辞退したり撤退したりしても罰則はありません。

自発的な参加

- この研究への参加は任意です。ご希望であれば、質問への回答や研究の一部への参加を拒否していただくことも可能です。
- さらに、データ分析前にデータの撤回を要請することができ、その場合も罰則や受給資格を失うことなく撤回できます。参加の可否の選択は、OCAD 大学（および／または本研究の他の機関／パートナー）との将来の関係、あるいは本研究に関与する研究者 Jiaxin Zou 氏とNancy Snow 氏との将来の関係に影響を与えるものではありません。

- この研究から撤退する場合は、研究期間中いつでも学生研究者に知らせるか、jiaxin.zou@ocadu.ca までメールで Jiaxin Zou に連絡してください。
- 研究への参加を取り消す場合は、参加終了後 10 日以内にJiaxin.zou@ocadu.caまでメールでJiaxin Zouにご連絡ください。取り消しの依頼を受領次第、参加者に関するすべてのメモと記録は、研究者のパスワード保護されたデバイスから完全に削除されます。手書きのメモは安全にシュレッダー処理されます。削除されたデータのコピーは一切保持されず、この研究に関連する分析や出版物にも掲載されることはありません。

結果の公表（チェック可能）

- この研究の結果は、研究者の主要研究プロジェクト（MRP）に掲載され、インクルーシブデザインに関連する学術報告書、デザイン展、会議などで発表される場合もあります。いずれの出版物においても、データは集計された形で提示されます。インタビューやアンケートからの引用は、ご本人の許可なく、ご自身の著作物として公表される

デザインのやり取りに関するフォローアップの連絡の可能性（チェック可能）

- この調査は、複数回の反復を含むインクルーシブデザインプロセスに従っているため、将来的にデザインの更新や追加のテストセッションが行われる可能性があります。現在のセッションへのご参加後、同様のセッションへの参加をご希望の場合は、下記のメールによる再接続に同意する「はい」にチェックを入れてください。

- このフォローアップにより、研究者はプロトタイプの改良版に関するフィードバックを収集し、変更によって使いやすくなったかどうかをより深く理解できるようになります。
- 連絡を受けることに同意しても、将来のセッションに参加する必要があるわけではありません。追加のテストへの参加は完全に任意となります。

連絡先情報と倫理審査

この研究についてご質問がある場合、またはさらに詳しい情報をご希望の場合は、お気軽にお問い合わせください。研究後、研究内容についてご質問がある場合は、上記の連絡先まで、研究責任者のJiaxin Zouまたは指導教員のNancy Snowまでご連絡ください。本研究は、OCAD 大学の研究倫理委員会（#7031）の審査を受け、倫理審査の承認を受けています。

この研究の参加者としての権利についてご質問がある場合は、以下の連絡先までご連絡ください。研究倫理委員会担当副学長室、研究・イノベーション担当 OCAD University 100 McCaul Street Toronto, M5T1W1 416 977 6000 x4368 research@ocadu.ca

合意

音声録音

☐ この調査のために音声録音されることに同意します。録音された音声がどのように保管され、破棄されるかを理解しています。

☐ この研究の目的で録音されることに同意しません。

デザインの反復のためのフォローアップの連絡の可能性

☐ はい、（あなたのメールアドレス）を通じて、今後の参加の可能性について連絡を受けることに同意します。______________

☐ いいえ、このセッション後に再度接続したくありません。

上記の研究に参加することに同意します。情報同意書に記載されている情報に基づき、この決定を下しました。研究について必要な追加情報を受け取る機会があり、今後質問する可能性があることを理解しています。この同意はいつでも撤回できることを理解しています。

名前：　＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿

署名: 日付:　＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿　＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿

このプロジェクトへのご協力ありがとうございます。このフォームのコピーを保管しておいてください。

Appendix B: Testing Protocol

Section 1: Scenario testing(20-25 min)

Task 1 – Before beginning the test, take a moment to freely explore the device.

You may:

- Pick it up
- Turn it around
- Press or touch any visible buttons
- Move it naturally as if you just found it on your kitchen counter

Scenario Context:

You are at home preparing **a creamy mushroom pasta** for dinner.
The recipe requires **about 2–3 tablespoons of milk** to finish the sauce.

When you open the fridge, you find a **half-used carton of Fairlife 2% ultra-filtered milk** that was opened a few days ago. The amount left is enough for your pasta, but you are **not sure whether the milk has started to spoil**. Using spoiled milk could ruin the dish and waste all the ingredients you have already prepared.

To avoid this, you decide to use the **handheld dairy testing device and its companion app** to check the milk before adding it to your recipe.

Task 2 - Pick up the dairy testing device from the kitchen counter. Your goal is to **turn the device on and connect it to the app** so you can begin testing the milk.

Task 3 - After the device is turned on, you pour 5ml **of the Fairlife 2% milk** into the sample cup provided with the device. You then attempt to **attach or align the sample cup with the device**, using the device's shape and physical cues to understand how the parts should fit together.

Task 4 - With the sample prepared, you open the app and navigate to the **menu**. Your goal is to **select the correct dairy product** that matches the milk you are testing.

Task 5 - Once the milk is selected in the app, you press the **main button on the device** to begin testing.

Task 6 - After viewing the result, you clear the current milk selection in the app so that the device is ready for a future test. You then **turn off the device** and place it back on the counter before continuing to cook.

Section 2: Short Interview After Prototype Testing (5 min)

Participants will be ask:

1. Were there any moments when you felt confused or uncertain during use?

   在使用过程中有没有感到困惑或不确定的地方?

   使用中に戸惑ったり、わかりにくいと感じたところはありましたか

2. Are there any features or functions you think could make it easier for you to use?

   有没有什么功能或设计会让它对你来说更易用?

   より使いやすくするために追加すると良い機能や要素はありますか?

3. Open question to follow up on something noticed by the researcher, for example:

I notice you trying to shake the device once you hold it, what does this action mean? Can you explain your understanding to me?

我注意到你拿到这个设备后试图摇晃它，这个动作是什么意思，你可以解释一下你的理解吗?

デバイスを入手後、振ろうとされているようですが、これはどういう意味でしょうか？ご説明いただけますか?

Appendix C: Device State Reference Sheet

	Mode/Status	LED	Sound	Vibration
	Power OFF & Bluetooth unconnected	N/A	N/A	N/A
	Bluetooth connecting/Ready to test	*Blue light slowly flashes*/Steady blue light	*Do-Re-Mi-Do played* ***once***/Short beep **once**	*Low intensity vibration pulses* ***3 times***/**2** short pulses
	Testing	Stable white light for **1** second	Very short and light beep for **twice**	**1** long pulse
	Test outcome: Safe	Steady green light	Slow, soft, low-pitched beep **twice**	**2** long pulses
	Test outcome: Danger	Flashing red light	Fast, high-pitched beep **four times**	**3** short and quick pulses
	Error	Red & blue light flashes rapidly	Short and **continuous** beepings	Short, **continuous** and strong pulses

Appendix D: Survey Material

Image & Respond Collection Form Content_English Version

Online Activity - Inclusive Design for Dairy Spoilage Detection: Supporting Users with Olfactory Impairments

Hi everyone! I'm a graduate student in the Inclusive Design program at OCAD University. I'm currently working on my Major Research Paper project, and this post is part of an insight-gathering activity for my research. My project focuses on exploring how interaction, form, and usability can be developed so that the design of a handheld device can benefit a broader range of potential users for a handheld device intended to help people with temporary or permanent olfactory impairment identify dairy spoilage in everyday kitchen environments. Considering the environment of the device, I'm interested in understanding how people perceive, choose, and interact with handheld kitchen tools, including preferences related to form, aesthetics, function, and usability. The insights collected from this activity will be used as design references to inform the form and interaction design of the device.

What you are invited to share (about 5 minutes):

• One handheld kitchen tool you like

• A short explanation of why you like it and what does the tool do (e.g., appearance, shape, function, or ease of use)

You may upload a photo you took yourself or a publicly available product image or screenshot.

Consent: By submitting the form, you confirm that you have read and understood the information above and agree to participate.

Please upload an image/photo of your favorite kitchen handheld tool.You may upload a photo you took yourself or a publicly available product image or screenshot.

Please avoid including any personal or identifiable information in images. If any identifiable details appear, even unintentionally, they will be anonymized prior to analysis.

添加文件 查看文件夹

Please briefly explain what does this handheld kitchen tool do, and why you like it. *

简短回答文本

Image & Respond Collection Form Content_Mandarin Version

乳制品腐败检测设备的包容性设计

打扰各位！我是 OCAD 大学包容性设计专业的研究生。我正在进行我的毕设项目所以发帖进行这次见解收集的活动，我的毕设专注于探索如何开发交互性、造型和可用性，使厨房用手持设备能够惠及更广泛的潜在用户，打造一款能够帮助暂时或永久嗅觉障碍者识别日常厨房环境中乳制品变质的手持设备。

考虑到设备使用的环境大多是厨房，我很想了解人们如何感知、选择和与手持厨房工具互动，包括与设备形态、美学、功能和可用性相关的偏好。通过这个活动收集到的见解将作为参考来完善设备的造型和交互设计。

我希望您分享的内容（大概五分钟可以完成）：
- 一个您喜欢的手持厨房工具的照片
- 简要说明喜欢它的原因以及工具的功能（例如外观、形状、功能或易用性）

上传自己拍摄的照片/公开的产品图片/截图都是可以的！

同意书：
提交表格即表示您已阅读并理解上述信息，并同意参与。

* **01** 请上传一个您喜欢的厨具的图片

* **01** 请上传一个您喜欢的厨具的图片

照片、网图、截图都是可以的！上传照片时请尽量避免暴露您的个人信息，但是请放心，所有问卷收集的图片数据都会在用于定性分析之前进行匿名化处理（如模糊、裁剪等修图方法），所有数据和您的信息都只有研究员（我）有权限查看，我将进行完全保密，并在完成照片和回答的收集后删除所有信息以保护您的个人信息安全。

\+
点击上传或拖拽
图片/文件至此处

ⓘ 单个图片/文件大小不超过300MB

* **02** 这是一个什么厨具，您为什么喜欢它呢?

请简略解释为什么该厨具的功能（以防一些不常见的厨具可能无法直观从外形判断其功能性），并用简单的一两句话解释您喜欢这个厨具的主要理由（比如审美考量、抓握舒适度、可用性、互动性等等角度）

请输入

Image & Respond Collection Form Content_Japanese Version

皆さんの好むキッチンハンドヘルド調理器具は何で、その理由を知りたいです

こんにちは! 私はOCAD 大学でインクルーシブデザインを専攻する大学院生です。 私は最終プロジェクトに取り組んでいるので、このインサイト収集活動のために投稿しています。私の志向は、インタラクティブ性、スタイリング、使いやすさを開発し、より幅広い潜在的なユーザーにリーチする方法に焦点を当てており、一時的または恒久的な嗅覚障害を持つ人々が日常のキッチン環境で乳製品の腐敗を識別できるハンドヘルドデバイスを作ることを目指しています。
デバイスが主にキッチンで使われる環境であることを考えると、人々が手持ちのキッチンツールをどのように認識し、選び、相互作用するか、デバイスの形状、美観、機能性、使いやすさに関する好みを理解したいと考えました。 このイベントで得られた知見は、デバイスのスタイリングやインタラクションデザインの洗練に活用されます。
共有してほしいこと(約 5 分でできます):
•お気に入りの手持ちキッチンツールの写真
• なぜ気に入ったのか、そしてツールが何をするのか(例:見た目、形状、機能性、使いやすさ)を簡単に説明してください。
ご自身で撮影した写真や、公開されている商品画像やスクリーンショットをアップロードできます。

同意: フォームを提出することで、上記の情報を読み理解し参加することに同意したものとみなされます。

お好きなキッチン用ハンドツールの画像/写真をアップロードしてください。ご自身が撮影した写真や、公開されている製品画像やスクリーンショットをアップロードしてもかまいません。 *画像に個人情報や特定可能な情報を含めるのを避けてください。もし特定可能な詳細が意図せず表示された場合でも、分析前に匿名化されます。*

添加文件　　査看文件夹

このハンドヘルドキッチンテールが何をするか、そしてなぜ気に入っているかを簡単に説明してください。 *

简短回答文本

Appendix E: Online Consent Material

Consent Form

Date: 2025/10/25
Project Title: Inclusive Design for Dairy Spoilage Detection: Supporting Users with Olfactory Impairments

Principal Investigator:	Faculty Supervisor:
Student: Jiaxin Zou	Nancy Snow
Faculty of Design	Faculty of Design
OCAD University	OCAD University
Jiaxin.zou@ocadu.ca	nsnow@ocadu.ca

PURPOSE

- This study is part of a graduate research project in the Inclusive Design program at OCAD University. The results will be used to support a graduate research project at that focuses on creating a more inclusive food safety device for everyday use.
- The goal is to explore people's preferences and insights related to handheld kitchen tools, such as form, function, usability, and interaction, in order to inform the inclusive design of a handheld device intended to help people with temporary or permanent olfactory impairment identify dairy spoilage in everyday kitchen environments.
- Participants will be invited to share a picture or link of their favorite kitchen tool and briefly explain why they like that kitchen tool. The purpose is to collect opinions from people using different social media (Reddit, RedNote, and SNS) to understand common and different preferences in kitchenware.
- The information collected will help the researcher summarize what features people value when they describe their favorite kitchen tool.
- To join, you need to be able to communicate in English/Mandarin/Japanese (Refers to users' cultural communities of Reddit, RedNote, and SNS).
- This research is conducted by Jiaxin Zou, a graduate student, as a part of a Major Research Project (MRP) under the supervision of Nancy Snow. It is not for commercial purposes and has no external funding.

WHAT'S INVOLVED

- As a participant, you will be asked to share a picture/photo of your favorite kitchen tool, and briefly explain what does the tool do and why you like it (Is it because of the good-looking appearance, functionality, or handy shape, etc.?) through an external form link (google/tencent form depends on accessibility to participants in different regions).
- Participation will take approximately 5 minutes of your time. You can take part in English, Mandarin, or Japanese, depending on the language you are most comfortable with.

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OCAD UNIVERSITY

- You will not need to provide any personal information. The only requirement is that you can read and respond in one of the 3 languages listed above, as the post will be shared on the social platforms Reddit, RedNote, and SNS. There are no costs or payments related to participation.

POTENTIAL BENEFITS

- There are no direct personal or financial benefits for participants in this research.
- However, by sharing your opinions and examples of kitchen tools, you will help the researcher better understand how people describe and choose the tools they use every day. Your participation supports inclusive design research that aims to make a handheld device easier and safer for everyone to use.
- The results of this study may help designers and researchers think about how to create products that meet the needs of a wider range of users, including people with different sensory or physical abilities.
- Although you may not receive any direct benefit, your contribution will help increase understanding of inclusive design in daily life and support future improvements in product design and accessibility.

POTENTIAL RISKS

There also may be risks associated with participation

- This study involves minimal risk to participants. There is no physical, emotional, or financial risks associated with participation.
- A small possible risk is that a participant's shared photo of kitchen tools may contain identifiable details, such as a reflection showing the participant's face or personal surroundings. To reduce this risk, the researcher will review all submitted images and apply anonymization techniques, such as blurring or cropping, to remove any identifiable features before analysis.
- As recruitment occurs in public online spaces, there is a small possibility that participants may encounter comments from other users. To minimize this risk, participants will be instructed not to share study-related content in comment sections and to submit materials only through the external form link. Public comments are outside the researcher's control and will not be used as research data.
- Overall, participation is considered to involve very low risk, and every effort will be made to protect participants' privacy and well-being.

CONFIDENTIALITY

- Because participation occurs via an external form rather than public comment sections, submitted images and responses will not be posted publicly. Comments made in public post sections are not collected or used as research data. While complete anonymity cannot be guaranteed, materials submitted through external form link (google/tencent form) will be treated as confidential.

- However, for research analysis, the researcher will not include or record any personal information that could identify participants. Usernames, account details, and any identifying text will not be collected. If participants share images that may contain identifiable details such as reflections or personal objects, the researcher will use Photoshop or similar editing tools to anonymize these images by blurring, cropping, or masking such areas.

- Data collected during this study will be stored on a password-protected personal computer accessible only to the researcher. No identifying information will appear in any reports or publications resulting from this study.
- Data will be deleted immediately once the Major Research Paper is completed.
- Access to this data will be restricted to Jiaxin Zou and Nancy Snow.

INCENTIVES FOR PARTICIPATION

- There are no incentives, payments, or rewards for participating in this online activity. Participation is completely voluntary.

VOLUNTARY PARTICIPATION

- Participation in this study is voluntary. You may choose whether or not to take part in this activity.
- Participation occurs by submitted an image and a short-written response through an external online form. Submission of the form indicates your consent to participate in this study.
- Because responses are collected anonymously for design insight analysis and are not linked to participants for follow-up, submitted images and responses cannot be withdrawn after submission. For this reason, participants are encouraged to carefully consider whether they wish to participate before submitting any materials.
- Choosing not the participate will involve no penalty or loss of benefits, and will not affect your relationship with OCAD University or the researchers involved in this study.

PUBLICATION OF RESULTS

Results of this study may be published in the researcher's Major Research Paper (MRP) at OCAD University and may be shared in related academic presentations or reports. All data will be presented in summarized and anonymous form. No individual participant will be identified in any publication.

CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please ask. If you have questions later about the research, you may contact the student research Jiaxin Zou or the Faculty Supervisor Nancy Snow using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University [7249#].

If you have questions regarding your rights as a participant in this study please contact:

Research Ethics Board c/o Office of the Vice President, Research and Innovation
OCAD University
100 McCaul Street
Toronto, M5T1W1
416 977 6000 x4368
research@ocadu.ca

同意书

日期：2025/10/25 项目标题：乳制品变质检测包容性设计：支持嗅觉障碍用户

首席研究员：
学生：邹嘉昕，安大略
艺术设计大学设计学院
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导师：
南希・斯诺
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nsnow@ocadu.ca

目的

- 这项研究是 OCAD 大学包容性设计项目研究生研究项目的一部分。研究结果将用于支持一个研究生研究项目，该项目的重点是为日常使用创建更具包容性的食品安全设备。

- 目标是探讨人们对手持厨房工具的偏好和见解，如造型、功能、可用性和交互性，以便为一款旨在帮助暂时或永久嗅觉障碍者识别日常厨房环境中乳制品腐败的手持设备提供包容性设计。

- 参与者将被邀请分享他们最喜欢的厨房工具的图片或链接，并简要解释他们为什么喜欢该厨房工具。目的是收集使用不同社交媒体（Reddit、RedNote 和 SNS）的人们的意见，以了解对厨具的常见和不同偏好。

- 收集到的信息将帮助研究人员总结人们在描述他们最喜欢的厨房工具时看重哪些功能。

- 要加入，您需要能够用英语/普通话/日语进行交流（指用户的 Reddit、RedNote 和 SNS 文化社区）。
- 这项研究由研究生邹嘉欣在南希・斯诺的指导下作为重大研究项目（MRP）的一部分进行。它不用于商业目的，也没有外部资金。

涉及什么

- 作为参与者，你将被要求分享一张你最喜欢的厨房工具的照片，并简要说明该工具的功能以及你喜欢它的理由（是因为外观好看、实用性还是方便的形状等），通过外部表单链接（谷歌/腾讯表单取决于不同地区参与者的可访问性）。

- 参与大约需要 5 分钟的时间。您可以使用英语、普通话或日语参加，具体取决于您最熟悉的语言。

・您无需提供任何个人信息。唯一的要求是你必须能阅读并回复上述三种语言中的一种，因为帖子会在 Reddit、RedNote 和 SNS 等社交平台上分享。
参与过程中无需支付任何费用或费用。

潜在好处

- 参与者在本次研究中没有直接的个人或经济利益。
- 然而，通过分享你对厨房工具的看法和示例，你将帮助研究者更好地理解人们如何描述和选择他们每天使用的工具。您的参与支持包容性设计研究，旨在让掌上设备更便捷、更安全地使用。

- 这项研究的结果可能有助于设计师和研究人员思考如何创造出满足更广泛用户需求的产品，包括具有不同感官或身体能力的人。

- 尽管您可能不会获得任何直接利益，但您的贡献将有助于增加对日常生活中包容性设计的理解，并支持未来产品设计和可访问性的改进。

潜在风险
参与也可能存在风险

- 这项研究对参与者的风险最小。参与没有相关的身体、情感或财务风险。

- 一个可能的小风险是，参与者共享的厨房工具照片可能包含可识别的细节，例如显示参与者面部或个人的倒影
环境。为了降低这种风险，研究人员将审查所有提交的图像并应用匿名技术（例如模糊或裁剪）来删除任何可识别的特征，然后再进行分析。

- 由于招募发生在公共网络空间，参与者很可能会遇到其他用户的评论。为降低风险，参与者将被指示不要在评论区分享研究相关内容，并仅通过外部表单链接提交材料。公众意见不受研究者控制，不会作为研究数据使用。

- 总体而言，参与被认为涉及非常低的风险，将尽一切努力保护参与者的隐私和福祉。

保密性

- 由于参与通过外部表单而非公开评论区进行，提交的图片和回复不会公开发布。公开帖子区的评论不会被收集或用作研究数据。虽然无法保证完全匿名，但通过外部表单链接（谷歌/腾讯表单）提交的材料将被视为机密。

・但在研究分析中，研究人员不会包含或记录任何可能识别参与者的个人信息。用户名、账户详情及任何可识别文本不会被收集。如果参与者分享可能包含可识别细节的图像，如倒影或个人物品，研究者将使用 Photoshop 或类似编辑工具通过模糊、裁剪或遮罩这些区域来匿名化这些图像。

- 本研究收集的数据将存储在仅研究人员访问的密码保护个人电脑中。本研究的任何报告或出版物中都不会出现任何身份信息。

- 主要研究论文完成后，数据将立即删除。
- 这些数据的访问将仅限于邹嘉欣和南希・斯诺。

参与奖励
- 参与此在线活动没有任何奖励、付款或奖励。
  参与完全是自愿的。

自愿参与
- 参与本研究为自愿。您可以选择是否参与此活动。

- 参与方式是通过提交图片和简短的回复，通过外部在线表单进行。提交表格即表示您同意参与本研究。
- 由于回答是匿名收集用于设计洞察分析，且不与参与者关联进行后续跟踪，提交的图片和回复提交后不得撤回。因此，鼓励参与者在提交任何材料前仔细考虑是否愿意参与。

- 选择不参与将不会产生任何惩罚或福利损失，也不会影响您与 OCAD 大学或本研究相关研究人员的关系。

结果公布
本研究结果可能会发表在 OCAD 大学的 Major Research Paper（MRP）中，并可能在相关学术报告或报告中分享。所有数据将以摘要和匿名形式呈现。任何出版物中不会透露任何参与者的姓名。

联系信息和道德许可
如果您对这项研究有任何疑问或需要更多信息，请询问。如果您以后对研究有疑问，您可以使用上面提供的联系信息联系学生研究 Jiaxin Zou 或教职主管 Nancy Snow。这项研究已经通过 OCAD 大学研究伦理委员会[7249#]进行了审查并获得了伦理许可。

如果您对您作为本研究参与者的权利有疑问，请联系：研究伦理委员会 c/o OCAD 大学研究与创新副校长办公室 100 McCaul Street Toronto， M5T1W1 416 977 6000 x4368
research@ocadu.ca

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同意書

日付:2025/10/25 プロジェクトタイトル:乳製品の腐敗検出のための包括的デザイン:嗅覚障害のあるユーザーを支援する

主任研究者:
学生:鄒嘉欣 OCAD 大学デザイン学部
Jiaxin.zou@ocadu.ca

教員監督:
ナンシー・スノウ
デザイン学部
OCAD 大学
nsnow@ocadu.ca

目的

- この研究は、OCAD 大学のインクルーシブデザインプログラムにおける大学院研究プロジェクトの一環です。その結果は、より包括的な食品安全装置の開発に焦点を当てた大学院研究プロジェクトを支援するために活用されます。
- 目的は、形状、機能、使いやすさ、インタラクションなどのハンドヘルドキッチンツールに関する人々の好みや洞察を探り、一時的または恒久的な嗅覚障害を持つ人々が日常のキッチン環境で乳製品の腐敗を特定できるようにするための包括的な設計に役立てることです。

- 参加者はお気に入りのキッチンツールの写真やリンクを共有し、そのキッチンツールがなぜ好きなのかを簡単に説明してもらいます。目的は、Reddit、RedNote、SNSなどの異なるソーシャルメディアを使っている人々の意見を集め、キッチン用品の一般的な好みや異なる好みを理解することです。
- 収集された情報は、研究者がお気に入りのキッチン用具を説明する際に人々が重視する特徴をまとめるのに役立ちます。
- 参加するには、英語/中国語/日本語(Reddit、RedNote、SNSの文化コミュニティを指します)でコミュニケーションができる必要があります。
- この研究は大学院生の鄒嘉欣氏が、ナンシー・スノウの指導のもと、大規模研究プロジェクト(MRP)の一環として実施しています。商業目的ではなく、外部からの資金もありません。

内容

- 参加者として、お気に入りのキッチンツールの写真や写真を共有し、そのツールが何をするのか、なぜ気に入っているのか(見た目が良いからか、機能性や使い勝手な形状など)、外部フォームリンク(GoogleやTencentフォームは地域の参加者のアクセシビリティに依存します)を通じて簡単に説明してもらいます。
- 参加にはおよそ5 分の時間がかかります。英語、中国語、日本語のいずれかで、自分が最も得意な言語に応じて参加できます。

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結果の発表

本研究の結果は、OCAD 大学の研究者の主要研究論文(MRP)に掲載される場合があり、関連する学術発表や報告書で共有されることがあります。すべてのデータは要約された匿名の形で提示されます。個々の参加者はいかなる出版物にも掲載されません。

連絡先情報および倫理クリアランス

この研究についてご質問や追加情報が必要な場合は、どうぞお尋ねください。研究について後で質問がある場合は、上記の連絡先情報を用いて学生研究員のJiaxin Zouまたは教員指導教員のナンシー・スノーにお問い合わせください。本研究はOCAD 大学の研究倫理委員会によって審査され、倫理承認を得ています[7249#]。

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Appendix F: Coding

	Theme Name(coding)	Definition
A	Ease of taking sample	Describes how easily participants could collect and transfer a sample into the measurement/sample cup.
B	Accuracy of sample volume	Describes whether participants kept the sample volume within the 5 mL limit during collection.
C	Ease of Component Attachment	Describes how easily participants could attach the sample cup to the device handle.
D	Awareness of Component Attachment	Describes whether participants recognized that the handle and sample cup were intended to be attached.
E	Perceived Device Weight	Describes participants' perceptions of the device's weight, including whether it felt light or heavy.
F	Perceived Ergonomics	Describes participants' perceptions of the device's ergonomics, including grip comfort and button accessibility.
G	Use of Prior Experience	Describes whether participants relied on prior experience with electronic devices when interacting with the prototype.
H	Concern About Sample Spillage	Describes participants' concern that the sample might spill after the attachment.
I	Ease of Power Operation	Describes how easily participants could turn the device ON and OFF.
J	Speed of Target Selection	Describes how quickly participants selected the dairy product target in the APP.
K	Attention to On-Screen Text	Describes whether participants noticed and read textual information in the App.

M	Recognition of Target Selection	Describes whether participants recognized that the product had been selected as the target when returning to the main page.
L	Recognition of Bluetooth Connection	Describes whether participants recognized that the device and App were successfully connected via Bluetooth.
N	Unexpected Interaction with Device Form	Describes unexpected user actions or interpretations caused by the device's physical form.
O	Recognition of App Status	Describes whether participants recognized the device status indicated by text in the App.
P	Perceived Speed of Results	Describes participants' perceptions of the speed of the testing process produced results.
Q	Source of Test Result	Describes whether participants obtained or confirmed test results from the device or the App.
R	Consistency of Device and App Feedback	Describes whether the device and App provided the same feedback at the same stage of the testing process.
S	User Uncertainty During Interaction	Describes moments when participants expressed uncertainty and proceeded with a tentative action.
T	Recognition of Reset Icon	Describes whether participants recognized that the reset icon cleared the selected product after testing.
U	Learning Curve	Describes participants' expectation that interaction with the device or App become easier with repeated use.
V	Selection of Test Container	Describes whether participants placed the sample in the intended sample cup or in the measurement cup for testing.
W	Perceived Non-Visual Feedbacks	Describes participants' perceptions of the Vibration and Sound feedback, or any other Non-Visual feedbacks.

X	Device Control Discoverability	Describes participants' initial attempts to understand the Hdevice's physical forms, controls and possible interactions when first encountering it.
Y	Misunderstandings about UI elements in App	Describe the actions that are inconsistent with the design process caused by the participants' misunderstanding of UI elements when interacting with the App.
Z	Fragile	Describes when participants mention the concern of breaking the device.
*	Iterative Suggestion	Describes the recommended ideas from participants.

Refer to feedbacks only about physical device

Refer to feedbacks only about App

Refer to feedbacks ambiguous (others)

1. **Ergonomics and Physical Comfort- Participants' perception of physical comfort and natural interaction with the device**

E	**Perceived Device Weight**
F	**Perceived Ergonomics**

2. **Device Operation- Participant interaction with device controls and hardware operations**

I	**Ease of Power Operation**
X	**Device Control Discoverability**

3. **Sample Preparation Process- User interaction with the sample collection and preparation process (Consider as the sub-branch of Device Operation)**

A	**Ease of taking sample**
B	**Accuracy of sample volume**
C	**Ease of Component Attachment**
D	**Awareness of Component Attachment**
H	**Concern About Sample Spillage**
V	**Selection of Test Container**

4. **App Interaction- Participant interaction with the mobile application interface**

J	**Speed of Target Selection**
K	**Attention to On-Screen Text**
M	**Recognition of Target Selection**
T	**Recognition of Reset Icon**
Y	**Misunderstanding about UI elements in App**

5. **Feedback Interpretation- How participants interpret system feedback from device or App**

L	**Recognition of Bluetooth Connection**
O	**Recognition of App Status**
P	**Perceived Speed of Results**
Q	**Source of Test Result**
R	**Consistency of Device and App Feedback**
W	**Perceived Non-Visual Feedbacks**

6. **User Expectations, Perceptions, and Suggestions- Participants' expectations, prior experiences, and design recommendations**

G	**Use of Prior Experience**

N	**Unexpected Interaction with Device Form**
S	**User Uncertainty During Interaction**
U	**Learning Curve**
*****	**Iterative Suggestion**
Z	**Fragile**

Appendix G: In-Person Feedbacks_DEVICE

A-F

	A:Ease of taking sample	B:Accuracy of sample volume	C:Ease of component attachment	D:Awareness of component attachment	E:Perceived device weight	F:Perceived ergonomics
P1	"(Pour the milk into the cap and then pour it from the cap into the measurement cup"-Sample preparation takes precise operation and attention	"(Pour the milk into the cap and then pour it from the cap into the measurement cup)"-Percise sample amount	"I was able to connect it pretty easily."-Connect handle and sample cup directly (before adding sample) "(Twist cautiously because of the liquid inside, used the measurement cup to hold the sample eventually)I think I attached it."-Attachment takes more time compares to attachment without sample inside	"I wasn't able to tell if there was, like, any twisting required, or if I just had to press it in, but I guess I just have to press it in."-Not sure it the attachment is intended to happen	"Yeah. I mean, it's light. I would say it's easy to hold."-Perceived device weight as light	"And there's one button that I can see.(picked up the handle, participant's thumb landed right on the button, they held in the position to pick it up and look around)"-Thumb can rest on the main button instinctively
P2	"And also when pouring the 5 ml sample earlier	"Okay. But I think the cup could be bigger. When pouring like	"Hmm… I'm not sure which side locks, because I don't want	N/A Participant is aware of component	N/A	N/A

	(actually poured into the measurement cup), it was too small. Really too small."-Measurement cup perceived as too small for sample preparation	this it's a bit inconvenient."-Used the measurement cup, the amount is accurate	to break it."-Difficulty of locking the components	attachment without questioning		
P3	"Also I think putting the sample in this measurement cup requires you to be very careful."-Difficulty of sample preparation "However, if someone has visual impairments, it would be very difficult to use. Preparing the sample itself already requires precise actions, so	"(attaches the device but the measurement cup with the sample is still outside)"-Collect sample with measurement cup, so the amount is accurate	"Oh, so you just press it slightly and then turn it. I thought maybe you had to press it down until you heard a click to lock it."-Expecting for sound confirmation when attaching the components	N/A Participant is aware of component attachment without questioning	N/A	" It did feel a bit strange earlier because the measurement cup and sample cup fit together so perfectly that I thought they were meant to be used together like that. Because they fit so well, it actually guided me to assemble them that way."-The fitness of sample cup and measurement cup leads the participant to use

	if you can't see it would be even harder."-Suggest sample preparation could be more difficult for people with visual impairments					them together for testing
P4	"Oh okay. (carefully pours the milk into the sample cup like measuring medicine, without using the measurement cup) "-Sample preparation take careful action " When pouring the milk, I wasn't very sure what 5 milliliters actually looks like. I was worried about pouring too much or too little."	"Oh okay. (carefully pours the milk into the sample cup like measuring medicine, without using the measurement cup) Is this right? But I'm not sure how much 5 milliliters actually is. (successfully connects the sample cup and handle) Is it like this?"-Inaccurate sample amount as measurement cup has not been used	"(observing, tries aligning the handle and sample cup, the motion looks smooth, then separates them and puts them back on the table) "-Smooth attachment before sample applied " Oh okay. (carefully pours the milk into the sample cup like measuring medicine, without using the measurement cup) Is this right? But I'm not sure how much 5 milliliters actually is. (successfully connects	N/A Participant is aware of component attachment without questioning	N/A	" It's very friendly for left-handed people." " And also the locking mechanism actually feels very convenient for me."-Locking mechanism perceived as left-hand convenient and friendly

	"Because I felt the cup was a bit small, and the milk bottle opening is quite large. I wasn't sure if I might accidentally pour too much."-Difficulty of sample preparation		the sample cup and handle) Is it like this?"-Careful but smooth attachment with sample			
P5	"I hope I won't spill it… I wish this sample cup (actually the measurement cup) could be bigger."-Difficulty of sample preparation	"Oh okay… five milliliters… five milliliters?! Oh this is five milliliters. I was just wondering how to determine five milliliters. (pours it into the measurement cup)"-Accurate amount of sample	"Oh okay. Now I'm a bit worried it might spill. It should already be locked—I heard a click earlier."-Attached successfully and heard the lock sound	"Hmm… at the beginning I thought the handle itself was already a complete unit. I didn't realize it was meant to work together with the sample cup until I saw the matching slot."-Lack of awareness of attachment motion initially	N/A	"And this part goes like this… (combines the measurement cup and sample cup, then connects them with the handle) Oh? It fits right in."-The fitness between sample cup and measurement cup leads the participant to put them together instinctively
P6	"But this measuring cup is	"But it says 5 milliliters… oh this is	"Okay. Is this where the light comes out?	"Okay. Is this where the light	N/A	N/A

	really small. Maybe making it bigger and adding measurement lines would be better."-Measurement cup perceived as very small for sample preparation	5 milliliters. (picks the measurement cup back up, easily pours some milk into it, then pours the milk from the measurement cup into the sample cup) "-Accurate sample amount	(looks at the hole on top and lightly taps the shell, tries attaching the handle and sample cup)" "Then align the sample cup with the device… how to align… like this? (attaches the sample cup to the handle) Done."-Smoothly attach the sample cup to the handle	comes out? (looks at the hole on top and lightly taps the shell, tries attaching the handle and sample cup)"-Notice the handle and sample cup are intended to connect		
P7	"Would it be better to just remove this? It's really small."-Perceived the measurement cup as really small for sample preparation, did not use is for collection	"Okay… how much is 5 milliliters? (picks up the sample cup and observes it, does not pick up the measurement cup again)" "(pours some milk directly into the sample cup, then tries attaching it to the handle, spending about 20 seconds	"Why won't this twist… oh, the opposite direction locks it… why is it this direction…" "The most obvious thing was the lock direction. It's opposite to the direction I'm used to, so at first I thought I was using the wrong amount of force and kept	N/A Participant is aware of component attachment without questioning	N/A	"Yes, something like that. If the button weren't there, I might actually have used it upside down."-The position of the button leads participant to use it in the direction of design intent "Oh, that's supposed to be used? I thought it was just the lid for

		figuring it out) Why won't this twist… oh, the opposite direction locks it… why is it this direction…"-Inaccurate amount sample because measurement cup is not used for sample collection	pressing harder, but later I realized the direction was wrong."-Difficulty of attaching components			the sample cup, like to keep things from spilling out."-The fitness between sample cup and measurement cup leads participant thinks the measurement cup is the lid of the sample cup
P8	"It's a bit dark here, so it's hard to see how much I've poured. I'm worried it might overflow."-Mentioned the difficulty of sample preparation because of the sample visibility in the sample cup	"(Picks up the sample cup and tries to pour milk into it.)\"-Inaccurate amount of sample	"Hmm… this lock and unlock… which direction is it? (Attempts to align the sample cup with the handle several times but fails.)"-Difficulty of attaching components because of the direction misunderstanding	N/A Participant is aware of component attachment without questioning	"The weight… It's not heavy. You could easily hold it with one hand. "-Perceived the weight as not heavy	"my thumb naturally rests on the button, which feels quite user-friendly."-Position of the button leads participant's thumb stay on the button naturally "Oh—because I felt like this part (the sample cup) is the base. So instinctively, when something is removed from its base, I feel like it should lie down."-

						Sample cup perceived as a base to hold the handle, leads to a lie-down way of putting back the handle "Well, since there was a lid (the measurement cup), I just felt like it should be closed. And since it could still lock together with the handle after closing it, I assumed that was probably correct."-The fitness between measurement cup and sample cup leads participant thinks the measurement cup is a lid for the sample cup
P9	"I feel like this milk might spill… (Pours milk into the measurement cup, then places	" (Pours milk into the measurement cup, then places the measurement cup inside the sample cup	"**R:** Oh, you assembled that very easily."-Attached components easily	" (Tries twisting the connection between the upper handle and lower handle, notices it	N/A	"That was my initial thought, but I feel like if this (measurement cup)

	the measurement cup inside the sample cup and connects it to the handle.)"-Easy and quick sample preparation	and connects it to the handle.)"-Inaccurate amount of sample		doesn't move, then observes the alignment at the bottom of the handle.) Oh, I see. You combine these two parts and then twist them together. Okay, I'm ready."-Notice the alignment between sample cup and handle		is just placed inside like this, " "Also, the shape makes it feel like the sample cup is the base of the measurement cup, almost as if it was designed just to stabilize it."-The shape of sample cup looks like a base of the measurement cup, and the fitness between them leads the participant want to put the measurement cup on the sample cup

H,I,N,U,V,W

	H:Concern about sample spillage	I:Ease of power switch	N:Unexpected interaction with device form	U:Learning curve	V:Selection of test container	W:Perceived non-visual feedbacks
P1	"My hands aren't super steady, so I don't want to make a mess..."-Concern about spillage on table	"I think the turning it up to Bluetooth was very easy,"-Thinks it's easy to switch the power	N/A	"But I think that after I would reuse it one or two times I would get the hang of it."-Repetition could be helpful	"(Twist cautiously because of the liquid inside, used the measurement cup to hold the sample eventually)I think I attached it."-Used measurement cup as a sample cup	N/A
P2	"Okay. But I think the cup could be bigger. When pouring like this it's a bit inconvenient. So I just put it in like this, right? But I'm worried it might spill…"-Measurement cup	"This is the power on, right? (tries pressing it) Oh, the blue light… the Bluetooth is…(check the cheatsheet) connected."-Power on succeed at the first attempt	N/A	"Okay. (long press)Now it's blue… preparing… Is it already connected or is it still connecting?"-Smooth execution after first exploration and practice " Actually it's not very clear. Because	"(puts the measurement cup inside the sample cup) "-Used measurement cup to test the sample "Oh! So this is the sample cup!"-Confusion between measurement cup and sample cup	" I feel like the vibration of this prototype might be a bit too strong. Yeah, it's a bit exaggerated. Normally devices we use, like phones, only vibrate slightly, but this vibration

	perceived as too small for sample preparation, concern of spillage	"(participant powers off)"-Power off interaction looks smooth and quick		it just shows connecting… Unless the cheatsheet mentions that this light pattern means it's connected. "-Importance of cheatsheet		feels quite strong."-Vibration perceived as too strong
P3	"This reminds me of something. When you were a kid, did you ever take cough syrup? The cap was actually a measuring cup, a bit bigger than this one, and it had milliliter markings on it. That design might make it less likely to spill."-Implies the concern of sample spillage	"For powering on, do I just press it once? I don't need to long press?"-Uncertain about how long they should press to power on the device "(quickly completes the task)"-Power switching becomes smoother once practiced at powering on stage	"(twists and accidentally breaks one clip) Oh my god, I'm sorry."-One of the clip accidentally breaks "(attaches the device but the measurement cup with the sample is still outside) Oh oh! I thought… I thought you attach it and then hold it up to scan the sample! (places the measurement cup onto the sample cup and attaches the	"(quickly completes the task)"-Power switching becomes smoother once practiced at powering on stage	"Oh oh! I thought… I thought you attach it and then hold it up to scan the sample! (places the measurement cup onto the sample cup and attaches the handle)"-Used the measurement cup	"Yes. The vibration is also quite noticeable."-Vibration helped and alarmed to notice the outcome

			handle)"-Sample stays outside of the device when testing			
P4	N/A	" So this is power on and power off. (discovers the power function, tries it once and puts it back) Okay, let's go." "(attaches the handle and sample cup together, quickly finds the switch and smoothly completes the power-on task) Connected successfully." "(powers off the device and puts it back)"-Smooth power switch actions	"Okay… (opens the lid on top of the handle to look inside and closes it again) (attaches the handle and sample cup together, quickly finds the switch and smoothly completes the power-on task) Connected successfully."-Open the lid on the top towards the circuit inside -Attach without sample applied before testing	N/A	"Oh okay. (carefully pours the milk into the sample cup like measuring medicine, without using the measurement cup) Is this right?"-Used the sample cup to collect sample directly	N/A
P5	"I hope I won't spill it… I wish	" I see there's a black button here. I	N/A	"(reads the scenario and Task 2) Okay.	"I hope I won't spill it… I wish	"Oh! Do re mi do-so? Haha the

	this sample cup (actually the measurement cup) could be bigger." "Oh okay. Now I'm a bit worried it might spill."-Concern about sample spillage with the sample applied	can keep pressing it, but it doesn't say how many presses turn it on or off. (presses the button quickly for several times)"-Not sure about the power on action with button initially "**R:** You can try pressing it in a different way. **P:** (long presses)"-Power on smoothly with hint from researcher		(long presses to power on)"-Powering on becomes smooth after practice for once "It's okay because I already figured out how to assemble it during the familiarization stage,"-Practice made the further attachment smoother	this sample cup (actually the measurement cup) could be bigger. (places the measurement cup onto the sample cup and successfully connects it with the handle) "-Used measurement cup for testing eventually	melody."-Notice the power-on sound feedback "It should already be locked—I heard a click earlier."-Heard a click sound for attachment "(presses the button) Oh white light—testing… Oh! Green. Two long vibrations and sound. Safe."-Notice the sound and vibration feedbacks
P6	N/A	"Okay, power on. (long presses) It's powered on."-Smoothly powered on "Okay. (quickly clears the selection and long presses to power off) It's	N/A	N/A	"Sample cup… is this the sample cup? (points to the correct sample cup)"-Finds out the right sample cup "But it says 5 milliliters… oh this is 5 milliliters. (picks	N/A

		off."-Quickly turn off the device			the measurement cup back up, easily pours some milk into it, then pours the milk from the measurement cup into the sample cup) "-Uses the sample cup to test spoilage eventually, action matches to the design intent	
P7	N/A	"That's okay. (long press the button and the device powers on) "-Directly powered on "(long presses the button and powers it on successfully) "-Directly powered on after initial exploration "(clears the selection and	"Can I just open it and take a sip?"-Condiser a more direct action of testing "It turned green, and green means it's safe, no problem. (removes the sample cup casually)"-Removed sample cup before power off	"The vibration is quite strong, actually. It surprised me a bit. But I think once people get familiar with the workflow, this vibration strength might actually help people rely less on visual feedback. After using it for a while, you could probably do	"Okay… how much is 5 milliliters? (picks up the sample cup and observes it, does not pick up the measurement cup again)"-Used sample cup for testing eventually	" Hmm… it's not absolute. The first time I used it I was a little surprised, but like I said it could also be helpful." "The vibration is quite strong, actually. It surprised me a bit. But I think once people get familiar with the workflow,

		powers off the device smoothly)”-Directly powered off		something else while testing, and the vibration alone could tell you what’s happening without looking at the light.”-Suggest strong vibration feedback would help user rely less on visual feedback after practices		this vibration strength might actually help people rely less on visual feedback. After using it for a while, you could probably do something else while testing, and the vibration alone could tell you what’s happening without looking at the light.”-Perceived the vibration feedback as strong, but thinks it would help users to reply less on visual feedback after practices
P8	“I’m worried it might overflow. I’m looking for the capacity of the sample cup. I	“(Picks up the device and long-presses to power it on and off once.)”-	“(Places the measurement cup on top of the sample cup.)”-Uses the measurement cup	“(Long-presses to power on the device.) It’s on.”-Powered on	“(Picks up the sample cup and tries to pour milk into it.)”-Uses the sample cup directly	“Oh, it’s safe. Because the light is green, and there’s a soft, slow, low-pitched

	actually don't know exactly how much to put in, but I feel like maybe up to this point where the shape of the cup changes?"-Concern about sample spillage	Smooth power switching "Also, for the power button, since there was no indication at first, it took a bit of trial to realize that a long press powers it on. "-Was not sure about switching mode action initially	as a lid of the sample cup while the sample is collected in sample cup "I see. I also noticed something during the test. Every time you put the device handle down, you placed it lying on the table. Why is that?"-Unexpected way of put down the device "Well, since there was a lid (the measurement cup), I just felt like it should be closed. And since it could still lock together with the handle after closing it, I assumed that was probably correct."-Use measurement cup as a lid, covered the sample cup when	smoothly after first practice "But once you do it once, it becomes clear."-Gets easier to trigger the switch with first-time practice	without collection with measurement cup	beeping sound. There are also two long vibrations."-Notice sound and vibration feedbacks

			components are aligned for testing			
P9	" I feel like this milk might spill…"- Participant's concern of spillage after components are aligned	"Okay. *(Presses the button once briefly, sees no response, then long-presses to power on.)*"-Turn on the device with short practice "**P:** *(Reads the task while simultaneously resetting the app and powering off the device.)* **R:** Wow, you finished that very quickly!"-Quickly powered off	"Unlock… twist it maybe? Hmm, it doesn't seem to move. (Tries twisting the connection between the upper handle and lower handle, notices it doesn't move, then observes the alignment at the bottom of the handle.)"-Tried to twist the upper and lower handle when notice the lock & unlock stickers	N/A	"I feel like this milk might spill… *(Pours milk into the measurement cup, then places the measurement cup inside the sample cup and connects it to the handle.)*"-Uses the measurement cup to hold the sample	"Probably yes. Green intuitively feels like "safe." And the sound and vibration are not sharp or urgent, so it doesn't feel like it's warning me."-Perceived vibration feedback and thinks it's not urgent and matches to the outcome

X & Z

	X:Device control discoverability	Z:Fragile
P1	"And there's one button that I can see."-Perception of single-button control	N/A
P2	" So there are no other buttons, right? Yeah, seems like it. (Leaves the device back to the table)"-Perception of single-button control "Yeah. Also if this is the sample cup, cleaning it might not be very convenient. There could be leftovers in the corner areas."-Concern about cleaning difficulty with prior experience of cleaning issue with sharp corners	"Hmm… I'm not sure which side locks, because I don't want to break it."-Concern of breaking prototype because participant does not sure the right twisting direction and don't want to break it with wrong direction and too much force
P3	" Is this the power button? I thought this was a speaker, like where the sound feedback comes from."-Interpretation of component function based on visual cues	N/A
P4	"I think it was more intuitive. It feels like you should assemble it first. Like when you buy furniture from IKEA, it comes disassembled, but before you use it you assemble it first. And the handle has this slot at the bottom that matches the sample cup, so I instinctively put them together."-Noticed the matching alignment between handle and sample cup	N/A
P5	" I see there's a black button here. I can keep pressing it,"-Notice a black button (looks obvious on the white handle) "And there's a blue light here on top. I'm not sure what it does—maybe it shines on the milk, and if something happens after scanning it, it means the milk has a problem."-Thinks the steady blue light of connected sign is the light to scan and test diary spoilage	N/A

	"Also from the bottom of the handle there's a white thin material here. What is that?"-Notice the water permeable membrane "It's okay because I already figured out how to assemble it during the familiarization stage,"-Figured the attachment before testing "Hmm… at the beginning I thought the handle itself was already a complete unit."-Initially thought the handle is a complete unit	
P6	"Okay. Is this where the light comes out? (looks at the hole on top and lightly taps the shell, tries attaching the handle and sample cup) It looks like a flashlight…Ok, I'm ready."- Exploring the device, assuming and find the right spot for LED feedback	N/A
P7	"Okay. (picks up the handle and looks at the bottom, touches the waterproof membrane) What is this thin white piece?"-Notice the water permeable membrane "Also, although the bottom of the sample cup looks wider and eventually you can tell that's the part touching the table, my first impression was that the device looked like a flashlight, and I almost wanted to use it upside down."-First impression as a flashlight, was about to use it upside down	N/A
P8	N/A	N/A
P9	"That was my initial thought, but I feel like if this (measurement cup) is just placed inside like this, connecting the sample cup to the handle might be risky because the milk could spill."-Thought the sample cup is a holder to prevent spillage "Mainly because the two parts (the upper handle and lower handle) have different colors, which made me think they could be twisted."-The different	N/A

	color between upper and lower handle leads the participant think they are intended to be apart “The shape of this lower cup has many hygiene dead corners that would be difficult to clean. ”-Concern about cleaning difficulty with prior experience of cleaning issue with sharp corners	

Appendix H: In-Person Feedbacks_APP

J,K,M,T,Y

	J: Speed of target selection	K: Attention to On-Screen Text	M: Recognition of Target Selection	T: Recognition of Reset Icon	Y: Misunderstandings about UI elements in App
P1	"Is this a description? Yes, so I'm selecting the dairy."-Select the target directly	"Okay, I see that there's a selection of brands, and I'm selecting the brand that I see on the bottle. "-Spend some time to check the text information of the selected product	"Well, there's a bar on the bottom of the display on the app that indicates that my milk is being tested. There's a logo for the brand, also a written indication that it's the right one."-Notice target selection from the change on testing target bar on the App	"Okay, I can't tell exactly what I'm supposed to be doing, so I'm going to attempt to do this press the reset button."-Not sure about the meaning of clear the milk selection,but intuitively tapped the reset button without hints	N/A
P2	"So now we use this… Fairlife 2%? Hmm… oh okay, this is select. (reads Task 4 again)"-Select the target directly	"Because if you just want to select this milk, do you really need that much information about it?"-Questioning the amount of text information	"I feel like it's the change in the testing target information…The color change of the block from grey to blue actually catches my attention more."-Understands the target selection by text and color changing in the target selection bar	"Oh okay, it's kind of like doing it again. (presses reset button)"-Notice the reset button, directly understood the meaning of the icon	"Yes. I thought those were options…So I originally thought those grey tags were selectable options under this milk, like lactose-free versions or sweeter versions, something like more detailed choices."-Product feature tags interpreted as options to select

P3	"Oh, menu… milk… this should be "fridge keep after open"… okay, selected."-Successfully selected without reminder, but initially tapped the feature tags	"Oh, menu… milk… this should be "fridge keep after open"… okay, selected."-Notice the text information	"I can see the icon in the bottom left showing the brand of milk. And during the selection process I noticed that this block changed—it was grey at first. After I selected it, it turned blue and now it shows the Fairlife icon and name."-Target selection confirmed with the changes in target selection bar	"(quickly completes the task)"-Reset smoothly without hint/instruction	"Yes. I thought they represented different versions of the milk under the same brand, or different features you could choose. Like you would select the one that matches the current state."-Product feature tags interpreted as selected attributes
P4	"Find the milk… (glances at the bottle) This one. (selects it)"-Smooth selection	N/A	"The milk picture in the bottom-left corner, and the blue box showing the name of the milk."-Target selection confirmed with the changes in target selection bar	"(directly taps reset button)"-Reset quickly	N/A
P5	" (reading the product description, taps one of the feature tags on the single product page but nothing happens, then presses the	"Oh now I understand—maybe low temperature changes can accelerate spoilage of this	"This blue section now shows the name of the milk. I think it wasn't there before. And at the top of the app it says "Ready to test," so I know it's ready."-Smooth recognition of the target selection	"(immediately presses the clear button) Clear. This feels like a reset, right? (long presses to power off) Oh—"-Reset directly, understands the meaning of reset icon	"Also the feature tags are almost the same size as the select button, so they look like selectable options—for example maybe there's a lactose-free version. Since they were grey buttons, I thought they might light up

	blue “select” button at the bottom right) Okay.”-Select successfully, but not directly	milk. ”-Read the product description			when selected, like a checklist.”-Product feature tags interpreted as selected attributes
P6	“Oh. (first taps the small square icon next to the target bar on the app, sees no response, then opens the menu and selects the milk)”-Taps the target image initially, then select the sample from the menu	“And the app shows “connected” at the top. Will that information change depending on what I do in the app?”-Text status bar on the top noticed	“This part here. (points to the testing target bar turning blue)”-Testing target bar shows the status to participant	“Okay. (quickly clears the selection and long presses to power off) It’s off.”-Quickly reset the target	“Oh! Because I thought it was like the three-line menu icon on websites. When you click it, it expands and shows categories. I don’t know why I felt that way—it’s actually just a small square.”-Image of target selection bar interpreted as page menu icon for open overlay
P7	“(quickly and smoothly selects it)”-Quick and smooth target selection	N/A	“There’s an icon that looks like the picture of this milk, and this area turned blue.”-Recognized the target selection with image and color changing of testing target bar	“(clears the selection and powers off the device smoothly)”-Understands the reset icon without reminder/instruction	N/A

P8	"Okay… first… and then select. Done."-Smooth and quick target selection	"This bar here shows "testing target," and the name of the milk appears there. "-Noticed text for selected status	"This bar here shows "testing target," and the name of the milk appears there. The small icon next to it also corresponds to the milk."-Understand the selected status by image and text	"This… (Looks at the reset icon.) I guess this means reset?(Clears the selection in the app.)"-Took several seconds, but understands the reset button without reminder/instruction	N/A
P9	"Menu… is it this one? Okay, selected."-Select the target smoothly and quickly without instruction	"Yes. The target text here appears and it turns blue."-Notice target selection by text	"Yes. The target text here appears and it turns blue."-Understands the target has been selected by text and color	"(Reads the task while simultaneously resetting the app and powering off the device.)"-Understands the reset button and clear the selection without instruction	N/A

Appendix I: In-Person Feedbacks_OTHER

LOPQ

	L: Recognition of bluetooth connection	O: Recognition of status	P:Perceived speed of testing outcome	Q: Source of testing outcome
P1	Notice the connection by the blue light referred to the cheatsheet	Notice the ‘Ready to test’ status from the status indication bar on the top of the interface page	Thinks the result came out quickly	Understand the testing outcome from the color of the light
P2	-Consult cheatsheet to interpret bluetooth connection -Expectation of additional visual feedback for bluetooth connection reminder	-App connection feedback notice after prompting -Understands the target selection by the change in target selection bar	-Directly understands the outcome	-Notice the pop-up message bubble -Green color intuitively interpreted as safe
P3	-Smooth recognition of bluetooth connection	-Confirm the bluetooth connection status with cheatsheet	-Perceived the result immediately	-Vibration helps to notice the feedback, instinctively understand the outcome from the color change
P4	-Recognized the connection from the App interface changes	-Understands the connection status by referring to the cheatsheet	-Smooth and directly recognition of the outcome	-Find out from the light instinctively, and then see the change on from the App
P5	-Notice bluetooth connected with the steady blue light refers to the cheatsheet	-Notice the status from the status bar on the top of the interface page	-Notice safe outcome directly	-Recognized outcome from color, vibration and sound feedback

		-Recognized the testing status from the LED feedback, and referred to the cheatsheet		
P6	-Recognized the bluetooth is connected by the steady blue light and the text in the App	-Understand the connected status by checking the cheatsheet	-Recognized the result when the color of light changes on the device	-Light color of the device and App interface change, and the pop-up message on the App convinced the outcome to the participant
P7	-Notice bluetooth connection before testing with scenario	Learned the connected status from the cheatsheet	-Directly understands the outcome by color changing	-Understands the outcome by color changing from the device
P8	-Can tell the bluetooth connection directly	-Can tell the bluetooth connection directly from the cheatsheet	-Understands the outcome quickly	-Notice the outcome from light, sound, and vibration refers to the cheatsheet, and the text
P9	-Notice the bluetooth connected directly	-Notice the bluetooth connected status with the light change from the device and App	-Understands the outcome quickly	-Understands the outcome from color of the light intuitively

RGS*

	R: Consistency of device and app feedback	G:Use of prior experience	S: Use uncertainty during interaction	*Iterative suggestion
P1	-Notice the matching status change on the device and App for bluetooth connection	-Long pressed the main button intuitively -Attempt to tap the reset button because of the icon seems caring the meaning of reset	-Uncertainty of attachment completeness	-N/A
P2	-Notice outcome information from both the device and the App	-Hold until power on based on prior experience of power on other devices -Applies prior experience of measurement cup for syrup medicine	-Uncertain of attachment for lock twisting direction -Uncertainty of how to lock handle and sample cup	-Suggest the measurement cup could be bigger -Suggestion of hiding the text information and make the select button bigger -Suggest the target selection bar could be bigger -Change the form of measurement cup -Suggest target selection button could be larger
P3	-Recognize the bluetooth connection based on changes in the App and multi feedbacks from the device	-Reference to similar existing product -Applies prior experience of lids with seam -Applies prior experience of texture of speakers -Applies prior experience of cough syrup for the measurement cup	-Uncertain about how long they should press to power on the device -Uncertainty of the stick notes on the device about the twisting direction -Uncertainty of the alignment intent	-Add text instruction on the device to inform the action for power on -Change the form of measurement cup -Make the sample cup and measurement cup fit less, make the measurement cup bigger, or change transparency of the material to make it more visible and easy for sample collection

		-Applies prior experience of using App-connected device, prefer to trigger test action from the App once ready to test -Prior experience different from the design intent, caused unexpected interaction		
P4	-Notice the consistency of bluetooth connection status from both device and App -See outcome from both device and App	-Understands the rest icon instinctively based on prior experience of similar icon -Applies prior experience from IKEA disassembled products	-Uncertainty about sample amount -Uncertainty of how to measure the sample amount	N/A
P5	-Notice the connection from both device and App at once	-Applies prior experience of some scan-testing device -Participant mentions their matching feature to the target audience of the design, and consider the design could be needed for them -Applies prior experience of powering on a mobile phone -Applies prior experience of interpretation of green color -Applies prior experience of similar reset icon	-Uncertainty of how long the pressing action to power on the device should be -Uncertainty of the sticky note instruction	N/A

P6	-Notice the change on the device and App at once	-Applies prior experience of flashlight to the appearance of the device -Applies prior experience of lids of containers -Applies prior experience of some similar measurement cups	N/A	-Suggests measurement cup lines
P7	N/A	-Applies prior experience of testing milk spoilage without smell it -Applies prior experience of locking direction for twisting-locking -Applies prior experience of a down-locking f juice blender	-Uncertainty of the locking direction -Uncertainty of the cup for sample preparation	N/A
P8	-Notice the matching change from both device and App	-Applies prior experience of old landline phones	-Uncertainty of the use for the button -Uncertainty of the sample amount	-The measurement cup could be taller to make the alignment impossible
P9	-Notice the change from device and App at the same time of bluetooth connection status -Understand the safe outcome from both text in	-Applies prior experiences of computers in sleeping mode and phones when powering on the device, but understands the difference with different context	-Uncertainty of the instruction sticker and twisting direction	-Suggestion of voice alert -Suggestion of take off the measurement cup, participant thinks the delicate sample collection process make the collection a nervous action

	the App and light from the device	-Applies prior experience of cleaning problem with sharp corners		

Appendix J: Feedback Summary

	Theme Name(coding)	Summary
A	Ease of taking sample	-Measurement cup too small 3/9 -Difficult (Preparation requires precise operation and attention 4/9 -Visual impairment accessibility issue 1/9 -Sample cup visibility issue 1/9 -Easy & Quick 1/9
B	Accuracy of sample volume	-Accurate sample amount 5/9 -Inaccurate sample amount 4/9
C	Ease of Component Attachment	-Easy before & after sample applied 3/9 -Difficult before & after sample applied 4/9 -Easy before, difficult after sample applied 2/9
D	Awareness of Component Attachment	-Aware 8/9 -Not aware 1/9
E	Perceived Device Weight	-Light, good to handle with single hand 2/9 -N/A 7/9
F	Perceived Ergonomics	-Thumb lies on the main button instinctively 3/9 -The fitness between sample cup and measurement cup leads the participant to put the measurement cup with sample on the sample cup when testing 5/9 -Locking mechanism perceived as left-hand convenient and friendly 1/9 -Sample cup perceived as base to hold the handle 1/9 -N/A 2/9

G	Use of Prior Experience	-Applies experience of measurement cup for cough syrup 3/9 -Applies experience of flashlight to the shape of aligned device 2/9 -Applies experience of scan-test device, eventually did not put sample in any of the cups 2/9
H	Concern About Sample Spillage	-Concern about sample spillage 6/9 -Not mentioned 3/9
I	Ease of Power Operation	-Easy/direct power switches 6/9 -Gets easy after exploration/practice for once 3/9
J	Speed of Target Selection	-Select directly and smoothly 6/9 -Select successfully, but initially tapped the feature tags 2/9 -Select successfully, but take some time 1/9
K	Attention to On-Screen Text	-Spend some time to check the text information 4/9 -Questioning the amount of text information 1/9 -N/A 2/9 -Notice target selection status with text information 2/9
M	Recognition of Target Selection	-Noticed from change on the testing bar 7/9 -Noticed from change on the image next to the testing bar 2/9
L	Recognition of Bluetooth Connection	-Recognized with blue light status referred to the cheatsheet 6/9 -Recognized bluetooth connection from change in the App interface 3/6 -Expectation of additional visual feedback for bluetooth connections status 1/9
N	Unexpected Interaction with Device Form	-Breaks one of the alignment clip 1/9 -Sample stays outside of the device when testing 2/9 -Opened the lid on the top of handle 1/9 -Removed sample cup before power off 1/9

		-Used the measurement cup as a lid of the sample cup when the sample is in the sample cup 1/9 -Place the handle lying on the table when put down 1/9 -Tried to twist the upper and lower handle when notice the lock & unlock stickers 1/9 -N/A 4/9
O	Recognition of App Status	-Notice the status from the status bar on the top of App interface 1/9 -Notice the status from the target selection bar from the App interface1/9 -Notice from cheatsheet 5/9 -Need prompt 1/9 -Notice both App and status referred to cheatsheet 2/9
P	Perceived Speed of Results	-Smooth and quick 9/9
Q	Source of Test Result	-Color changing noticed first and instinctively 9/9 -Noticed pop-up bubble 2/9 -Noticed multi-model feedback 4/9
R	Consistency of Device and App Feedback	-Recognized consistency 8/9
S	User Uncertainty During Interaction	-Uncertainty of attachment 3/9 -Uncertainty of locking direction (and stick notes) 4/9 -Uncertainty of sample amount 2/9 -Uncertainty of the time of holding button to switch power 2/9
T	Recognition of Reset Icon	-Intuitively/quickly/directly tapped reset button without prompt 9/9
U	Learning Curve	-Repetition/practice would help the interaction smoother 4/9 -Importance of cheatsheet 1/9 -Suggest strong vibration feedback would help user rely less on visual feedback after practices 1/9

		-N/A 3/9
V	Selection of Test Container	-Measurement cup 5/9 -Sample cup directly without measurement 3/9 -Hold with sample cup but covered with measurement cup when testing 1/9
W	Perceived Non-Visual Feedbacks	-Vibration perceived as too strong 1/9 -Vibration helped to alarm/rely less on vision 2/9 -Notice the power on melody 1/9 -Click sound for attachment 1/9 -Notice vibration and/or sound matches to the outcome 3/9
X	Device Control Discoverability	-Noticed single-button control 3/9 -Concern about cleaning difficulty 2/9 -Button perceived as a speaker because of the 3D printed texture 1/9 -Noticed the matching alignment between handle and sample cup 7/9 -Thought the steady blue light is the light for dairy spoilage scanning 1/9 -Noticed the water permeable membrane 2/9 -Initially thought the handle is a complete unit 1/9 -Noticed the place for light feedback 1/9 -First impression as a flashlight, was about to use it upside down 1/9 -Though the sample cup is a holder to prevent spillage 1/9
Y	Misunderstandings about UI elements in App	-Product feature tags interpreted as selected attributes 3/9 -Image of target selection bar interpreted as icon of open overlay 1/9 -N/A 5/9
Z	Fragile	-Concern of breaking prototype 1/9
*	Iterative Suggestion	-Mesurement cup could be bigger

		-Remove measurement cup -Form reconsider for measurement cup -Selectable visibility of text information -Target selection bar bigger -Larger selection button -Voice alert

Appendix K: Online Forms Responses

Number	Image	Reason	Essential Reason
1		This is a handheld electric mixer with three whisk attachments. I like it because: (1) it has strong power and quickly incorporates air when whipping egg whites or cream; (2) it is lightweight and easy to control; (3) it has great cost-performance and can handle most dessert mixing tasks while being much cheaper than a stand mixer.	Function – efficiency, power, usability
2	IMAGE NOT AVAILABLE: https://www.lazada.com.ph/products/kochblume-spatula-spoon-ladle-set-food-grade-silicone-non-stick-kitchen-cooking-tools-morandi-series-size-s-for-small-pots-and-cooking-baby-food-i4935234540.html	The color looks nice. It is small and lightweight, so it is not tiring to hold.	Aesthetics – color / Form – lightweight size
3	IMAGE NOT AVAILABLE:	A silicone spatula that does not damage non-stick cookware. The metal handle	Function – protects cookware / Form –

	https://www.kitchenstuffplus.com/zwillingr-pro-silicone-slotted-turner-black-stainless-steel	has a nice texture and is easy to clean.	material quality
4		Silicone does not damage non-stick coating and also provides heat insulation. It can be used for stir-frying, scooping noodles, and even flipping food in the oven without wearing gloves.	Function – heat resistance, versatility
5	IMAGE NOT AVAILABLE: https://www.mycarote.com/products/cashew-detachable-cookware-set-19pcs?srsltid=AfmBOoqbYxksye-p_c4qc1412ZyjGU7Hb72I05Hg-9_AnNaWhAtVsJ7g&	I like this type of pot (not necessarily this brand). The handle can be detached so the pot can be used like a bowl or serving dish. After cooking soup, removing the handle allows it to be placed directly on the table, which is more convenient and visually cleaner.	Function – modular usability / Aesthetics – cleaner presentation

6	IMAGE NOT AVAILABLE: https://www.jocgoods.com/products/japanese-wood-handle-peeler-and-julienne-peeler-set	First, it looks very nice. Second, it is very useful for peeling potatoes. It saves effort and is an essential kitchen item.	Function – peeling efficiency / Aesthetics – appearance
7	IMAGE NOT AVAILABLE: https://www.amazon.ca/Amazon-Basics-Classic-8-Inch-Rivets/dp/B09WW6VGHX	Comfortable and convenient. It is the only kitchen tool I really like because the knife feels sharp yet soft when using it.	Form – ergonomic comfort
8	IMAGE NOT AVAILABLE: https://www.walmart.ca/en/ip/Fish-Bone-Tweezers-Fish-Bone-Remover-Stainless-Steel-Fish-Bone-Remover-Slant-Tongs-Pick-Up-Craft-Tool/4SGMGW1BC7G0	Tongs that can do many tasks. They can be used like chopsticks or for stir-frying. The raised middle section allows the tongs to rest on the table without contaminating the tips.	Function – multifunctionality / Form – hygienic resting design
9	IMAGE NOT AVAILABLE: https://www.wmf.com/de/en/poultry-shears-3201002962.html	Kitchen scissors that can be operated with one hand. The design is convenient and includes a spring. It is multifunctional and can cut bones. The thumb position is designed to prevent injury when applying strong force.	Function – safety, efficiency / Form – ergonomic grip

10		A wooden spatula that can be used for almost any dish. It will not scratch the pan and is easy to clean and store.	Function – cookware protection, easy maintenance

11		A cooking spatula with a heat-insulated handle and a durable metal front.	Function – heat protection, durability
12	IMAGE NOT AVAILABLE: https://salter.com/products/manual-pull-cord-food-chopper.html	I used to buy electric garlic choppers but found them inconvenient: uneven results, long button pressing, blades getting stuck, and needing charging. This manual pull chopper is lightweight, easy to use, produces evenly chopped ingredients, and looks good.	Function – reliability, convenience / Aesthetics – appearance
13	IMAGE NOT AVAILABLE:	One side peels, one side shreds, and the middle can grind ginger or garlic (though that part is rarely used). The blade is	Function – multifunctionality /

	https://www.amazon.ca/Multi-Potato-Peeler-purple-Purple/dp/B0D9PP1MKT	sharp and very practical for people who struggle with knives. It is small and portable, though the colors are overly saturated and not very attractive.	Form – compact size
14		A rice scoop with textured bumps that reduce rice sticking. The flat bottom allows it to stand upright on the table to avoid contamination.	Function – anti-stick usability / Form – self-standing base
15	IMAGE NOT AVAILABLE: https://orders.cheesemeatboard.com/mini-cheese-cleaver	A mini chef's knife designed for people less skilled with knives. The shorter blade and longer handle improve balance and control, making precise cutting easier and	Form – ergonomic control / Function – precision cutting

		safer, especially for people with small hands.	
16	IMAGE NOT AVAILABLE: https://pingu.fandom.com/wiki/Cimuyidao_Studio	The appearance is cute and cleverly uses the shape of a penguin, with handles resembling wings.	Aesthetics – playful form inspired by animal shape
17		The tool I chose is a lemon squeezer. You place the lemon in between, and press down on handles. I like it because it's easy to use, designer-friendly, doesn't strain hands and minimizes mess.	Function – usability, efficiency / Form – ergonomic grip

18		This item helps peel things, I like it because I feel I can grip it well and it's easy to clean. I only recently realized the head of the tool is for circling/scooping out spores which is a cool feature	Function – peeling + seed removal / Form – comfortable grip
19	IMAGE NOT AVAILABLE: https://www.kitchenaid.ca/en_ca/countertop-appliances/hand-blenders/hand-blender-products/p.kitchenaid-go-cordless-hand-blender-with-12v-max-removable-battery.KHBRV71BM.html	This is an immersion blender, which I mainly use for making soups but can be used for a lot of other blending! I like how easy it is to clean, store and use. It has a bit of a learning curve as if you lift it while using it, the liquid splashes everywhere! But once you learn the technique its great and makes you feel like a chef	Function – versatility, easy maintenance

20		It's a potato masher and it has no presence of design. It's super normal and honest. It mashes potatoes well. It is unapologetically practical and works well. It's old and there is no plastic. The wood handle is sturdy and weathered. The metal masher bit is a continuous thick gauge wire. It transfers energy from my body to it without fanfare, fanfare	Function – effective force transfer / Form – durable material

Appendix L: Alternative Approaches Assessment and Application Feature Requirements

Alternative Approaches Assessment

Alternative Approach	Brief Description	Limitations
Hardware-only interaction (single-threshold detection)	• Standalone handheld detection device • Operated through a single physical control (e.g., one button) • Uses a fixed, unified threshold to determine spoilage • Does not require external software or mobile devices • Designed for simple and immediate operation	• Cannot differentiate between different types of dairy products • Applies the same spoilage threshold across all food contexts • Fails to account for acceptable variation in fermented or processed dairy • Risks false positives or false negatives in spoilage assessment • Oversimplifies a context-dependent food safety problem
Multi-button on-device interaction	• Handheld detection device with multiple physical buttons	• Physical buttons provide limited capacity for complex input

Alternative Approach	Brief Description	Limitations
	• Allows users to switch between modes or settings directly on the device • Enables limited input without relying on a mobile application • All interaction occurs on the device hardware • Designed to expand functionality through physical controls	• Mode selection becomes difficult to scale with increasing product variety • Requires users to memorize button functions or combinations • Increases cognitive load and risk of user error **“***Since many years not all users are experts or nerds. And even if they were they do not want to be. Systems are increasingly complex and users do not get extra memory.* *(Veer, 2008) “* (van der Veer, G. C. (2008). Cognitive ergonomics in interface design – Discussion of a moving science. Journal of Universal Computer Science, 14(16), 2614–2629.)

Alternative Approach	Brief Description	Limitations
		• Reduces accessibility for users with motor or sensory impairments
On-device touchscreen interface	• Handheld detection device with a built-in touchscreen display • Allows users to input selections and view feedback directly on the device • Supports more complex interaction than physical buttons • Operates independently without requiring a mobile app (Smart phone won't be the limitation of using) • Integrates input, sensing, and feedback into a single device	• Increases device complexity, cost, and power consumption • Touchscreens reduce tactile feedback and eyes-free usability • Small screen size limits clarity and readability • Introduces additional points of failure in a handheld device • Conflicts with the goal of maintaining a minimal and robust sensing tool
Data-driven food quality detection applications e.g. BBQ go https://apps.apple.com/ca/app/bbq-go/id1163595179	• Bluetooth-enabled food monitoring application	• Does not support context-dependent interpretation of food quality

Alternative Approach	Brief Description	Limitations
	• Connects to external temperature probes (hardware sensors) • Displays real-time numerical temperature data • Allows users to set threshold-based alerts • Focuses on data presentation rather than interpretation	• Lacks mechanisms to differentiate acceptable thresholds across different food types • Places responsibility for food safety judgment entirely on the user • Assumes users can interpret sensor data and assess risk independently • Not suitable for dairy spoilage assessment, where spoilage criteria vary by product type
Data-centric Bluetooth sensor applications e.g. Inkbird Smart Home Smart Life https://apps.apple.com/ca/app/inkbird/id1589369968	• Bluetooth-enabled monitoring application for external sensors • Connects to temperature, humidity, or environmental probes • Displays real-time numerical sensor data	• Focuses on raw data presentation rather than interpretation • Assumes users can define appropriate thresholds independently

Alternative Approach	Brief Description	Limitations
	• Allows users to set custom thresholds and receive alerts • Emphasizes data tracking and visualization	• Lacks contextual differentiation between different food products • Places decision-making responsibility entirely on the user • Does not support context-dependent spoilage judgment for dairy products
Mode-selection appliance applications e.g. LG ThinQ https://apps.apple.com/ca/app/lg-thinq/id993504342 Very similar App: XiaoMi Home https://apps.apple.com/ca/app/xiaomi-home/id957323480	• Companion applications for brand-specific smart home appliances • Connect to devices via Wi-Fi or Bluetooth • Allow users to select predefined modes or programs • Provide status feedback and basic performance information	• Limited to appliances within a closed brand ecosystem • Predefined modes do not support fine-grained, context-specific input • Do not allow users to define or modify sensing thresholds • Not designed for food quality or spoilage assessment

Alternative Approach	Brief Description	Limitations
	• Designed to support appliance operation rather than sensing interpretation	• Unsuitable for supporting product-specific spoilage criteria across diverse dairy types
Device configuration and parameter tuning applications e.g. Sennheiser Smart Control https://apps.apple.com/ca/app/sennheiser-smart-control/id1408526071	• Companion application for Sennheiser audio devices • Connects to devices via Bluetooth • Allows users to adjust device parameters (e.g., sound profiles, noise cancellation) • Provides feedback related to device status and performance • Designed for personalized configuration rather than decision support	• Relies on users' sensory perception and personal preference • Does not perform interpretation or judgment on behalf of the user • Configuration-oriented rather than context-aware • Not designed to support safety-critical or risk-based decisions • Unsuitable for food spoilage assessment requiring objective judgment

Features and Requirement table

This table identifies the minimum application requirements necessary to support user testing of a handheld dairy spoilage detection device. The application functions as a contextual input layer, enabling context-dependent evaluation without acting as a primary sensing or decision-making system.

Requirement (Simple version of Aspiration)	Current Situation (What happened when there's no APP, only a handheld device)	Aspiration (Desired Condition)	Functional Requirement (What the App needs to do)	Non-functional Requirement	Priority	Design Rationale
Selecting dairy product type	Without an APP, the handheld device applies a unified spoilage threshold across all dairy products, regardless of differences between fresh, fermented, or processed items.	Users can easily specify the type of dairy product so that spoilage assessment reflects product-specific criteria.	The application needs to allow users to browse/search and select dairy product categories (e.g., milk, yogurt, cheese) before the detection.	-Interaction should be simple and impose minimal cognitive load. -Product categories should be clearly labeled and easy to understand.	Must	-Limitations identified in Alternative Approaches Assessment Table -Research goal of context-dependent spoilage assessment
Linking Product Selection to Detection Logic	The device cannot adjust its evaluation logic/testing threshold based on the specific dairy product being tested.	The selected dairy product type is automatically linked to the appropriate spoilage evaluation logic.	The application must associate the selected product type with a corresponding detection threshold or evaluation model.	The linkage should occur automatically without requiring user interpretation or manual configuration.	Must	Research objective to reduce user responsibility for interpreting sensor data

						van der Veer, G. C. (2008). Cognitive ergonomics in interface design – Discussion of a moving science. Journal of Universal Computer Science, 14(16), 2614–2629.
Confirming Active Product Context	Users have no way to verify which spoilage standard is currently applied by the device.	Users can clearly confirm which dairy product context is active before starting detection.	The application must display the currently selected dairy product type prior to detection.	-Confirmation should be visually clear and immediately noticeable. -The interface should avoid dense text or technical terminology.	Must	Risk of user error identified in hardware-only and multi-button approaches
Preventing Misuse and Configuration Errors	Detection can be initiated without confirming whether the correct context has been selected, increasing the risk of misuse.	The system should prevent detection from proceeding without appropriate context selection.	The application must prevent detection from starting if no dairy product type has been selected.	-Error prevention should be passive and non-intrusive. -The system should guide users rather than issue warnings.	Must	Limitations related to unified thresholds and mode ambiguity identified in Alternative Approaches

						Assessment Table
Maintaining a Minimal Interaction Flow	Complex interfaces or excessive options can distract users from the handheld device and increase cognitive load.	The application should support the detection process without becoming the primary interface.	The application must support a minimal interaction flow with a limited number of steps.	The interface should avoid unnecessary features such as data visualization, historical tracking, or advanced analytics.	Ideal	Design goal of keeping the handheld device as the primary interaction point
Bluetooth connection between device and application	Without an APP, the handheld device cannot establish a communication channel for transmitting contextual input or configuration data.	The handheld device can reliably connect to the application to receive contextual input prior to detection.	-The application must support Bluetooth pairing and communication with the handheld device. -The application must be able to transmit selected context information to the device.	-Bluetooth pairing should be simple and require minimal user interaction. -Connection status feedback should primarily be communicated through device-based indicators (e.g., LED lights), rather than fully relying on the application interface (but still needs to be visible on the APP).	Must	-System architecture requirements -Design goal of keeping the handheld device as the primary interface

Community-contributed reference database	The App, once it exists, will rely on predefined product categories, limiting coverage of less common dairy brands and products.	Users can contribute and share reference spoilage thresholds for specific dairy products, expanding the range of selectable detection contexts.	-The application may allow users to upload reference spoilage threshold values associated with specific dairy products. -The application may allow other users to search and select contributed product entries as optional detection thresholds.	-User-contributed data should be clearly labeled as non-authoritative reference information. -Contribution and selection processes should be simple and optional. -The system should avoid presenting shared data as definitive food safety standards.	Ideal	-Anticipated scalability challenges related to product diversity -Inclusive design principles supporting user participation and co-creation
Anonymous contribution of reference data	User-contributed data systems often require user accounts, increasing privacy concerns and system complexity.	Users can contribute reference spoilage thresholds without the need for personal identification or account creation.	The application may support anonymous submission of reference threshold data to the shared database.	-Contributions should be clearly labeled as user-generated and non-authoritative. -The system should avoid collecting personally identifiable information.	Ideal	-Ethical considerations related to data privacy -Scope control for research-focused prototyping

Language and text size customization	Static interfaces typically assume a fixed language and text size, which may limit accessibility for users with different language backgrounds or visual needs.	Users can interact with the application in their preferred language and adjust text size according to their individual needs.	-The application may allow users to select from multiple interface languages. -The application may allow users to adjust text size within the interface.	-Language selection should be clear and easy to access. -Text scaling should preserve layout clarity and readability. -Adjustments should apply consistently across the application.	Ideal	-Inclusive design principles -Consideration of diverse user abilities and language backgrounds
In-app instructions and usage guidance	-Usage instructions are typically provided only through a physical product manual, which may be lost or inaccessible. -Text-heavy instructions may not be suitable for users with reading difficulties.	Users can easily access clear guidance on how to use the device and application whenever needed.	-The application may provide basic usage instructions for the handheld device. -Instructions may be presented in both short video and concise text formats.	-Guidance should be easy to access and optional. -Content should be concise and focused on essential steps only. -Video content should be short and visually clear.	Ideal	-Accessibility considerations -Risk of user error due to missing or misunderstood instructions
In-app Detection Result Display	Users currently rely primarily on the device's on-body multimodal feedback (e.g. LED light, sound, vibration)	Users should be able to review and understand the detection result clearly after the test	After a test is completed, the application must display the detection	The information must be easy to understand, non-technical, and accessible, using	Must	-Inclusive design consideration -Scenario based reasoning (e.g. user may forget

	to understand spoilage status. These signals are brief, abstract, and may be difficult to interpret.	has completed, without only relying on real-time physical feedback from the device. The APP system should support reflection and decision-making by presenting results in a more explicit and interpretable form.	result directly in the app, including: -the spoilage status of the selected dairy product. -A simple, human-readable recommendation (e.g. safe to consume, consume soon, discard), using text and/or basic visual indicators.	clear language and/or intuitive visual cues rather than abstract signals or numeric data.		the meaning of the LED feedback)
Clear Current Selection	If an APP exists, after a test is completed, the system remains in a “product selected” state and continues to display the detection result and consumption recommendation for the previously tested dairy product. Without a way to clear this state, users may experience confusion when	Users should be able to easily reset the system from a completed test state back to a neutral state with no product selected, allowing them to begin a new test with a different dairy product without ambiguity.	The application must provide a function that allows users to clear the currently selected and tested dairy product, returning the system to a “no product selected” state and enabling a new product to be chosen for the next test.	The reset process should be clear and unambiguous, avoiding accidental data loss while clearly communicating that the previous test state has been cleared.	Must	-design rationale -scenario-based reasoning

	attempting to test a different product.					

Appendix M: REB Approval Letter

REB Application Approved Summarize

do-not-reply-ocadu@researchservicesoffice.com

To: Jiaxin Zou; Nancy Snow

Cc: Bryan Weissenboeck

Fri 2026-01-16 3:22 PM

January 16, 2026

Prof. Nancy Snow
Faculty of Design
OCAD University

File No: 102839
Approval Date: January 16, 2026
Expiry Date: January 15, 2027

Dear Prof. Nancy Snow and Jiaxin Zou,

The Research Ethics Board has conducted a delegated review of your application titled 'Inclusive Design for Dairy Spoilage Detection: Supporting Users with Olfactory Impairments'. Your application has been approved. You may begin the proposed research. This REB approval, dated January 16, 2026, is valid until: January 15, 2027. Your REB number is: 2026-08.

IMPORTANT NOTE - The standard conditions for REB approval are as follows:

a) Throughout the duration of this research project all requests for modifications, renewals, and serious adverse event reports must be submitted via the ROMEO Research Portal.

b) Any changes to the research that deviate from the approved application - including changes to faculty supervisors or project team members - must be reported to the REB using the Amendment Form available on the ROMEO Research Portal. REB approval must be issued before changes can be implemented.

c) If you have received approval for more than one year, you are required to submit an Annual Progress Report Form via the ROMEO Research Portal every year as detailed in your approval letter. The Annual Progress Report Form is a very brief form that asks about any changes or adverse that may have occurred during the conduct of your research. REB approval of the Annual Progress Report Form must be issued before research activities involving human participants may continue.

d) If your research will continue beyond January 15, 2027, you must submit a Renewal Form via the ROMEO Research Portal before January 01, 2027. REB approval must be issued before research activities involving human participants may continue.

e) If your research ends on or before January 15, 2027, you must submit a Final Report Form via the ROMEO Research Portal to close out REB approval monitoring efforts. The Final Report Form is a very brief form that asks about any changes or adverse that may have occurred during the conduct of your research.

FOR STUDENTS: Please note that all applications and events must be submitted by your Faculty Supervisor on your behalf. This action is a proxy for supervisory sign-off and lets the REB know that your Faculty Supervisor has reviewed and approved the contents of your submission.

Please note that failure to comply with these conditions and the Tri -Council Policy Statement (TCPS) 2 may result in withdrawal of approval and/or impact your ability to apply for future REB review.

Information about ROMEO and OCADU's REB process can be found here: https://ocadu.topdesk.net/tas/public/ssp/5555c16a-0c8c-4fcf-9161-9929dc59b768

If you have any questions about the REB review & approval process, please contact Bryan Weissenboeck, Research Ethics Advisor, at bweissenboeck@ocadu.ca

If you encounter any issues when working in the Research Portal, please contact our system administrator via research@ocadu.ca.

Sincerely,

Dr. Michelle Miller
Chair, OCAD University Research Ethics Board

Reply | Reply all | Forward