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Public Perceptions of Smart Pharmaceutical Packaging in Ireland: Exploring Digital Trust, Medication Adherence, and Adoption Readiness in Chronic Disease Management

A thesis submitted in partial fulfilment of the requirements for MSc in Digital Transformation (Life Science)

Innopharma Faculty of Pharmaceutical Sciences
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DECLARATION

I hereby confirm that the dissertation titled “Public Perceptions of Smart Pharmaceutical Packaging in Ireland: Exploring Digital Trust, Medication Adherence, and Adoption Readiness in Chronic Disease Management” submitted for the degree of MSc in Digital Transformation (Life Science) is a research work done by me, and that all sources used have been acknowledged with complete references.

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Aabi Anilan

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

QR- Quick Response

MEMS - Medication Event Monitoring Systems

TAM- Technology Acceptance Model

UTAUT- Unified Theory of Acceptance and Use of Technology

GDPR- General Data Protection Regulation

PIL- Participant Information Leaflet

SPSS- Statistical Package for Social Sciences

EU- European Union

WHO- World Health Organization

ABSTRACT

This study demonstrated that although there is still a lack of public awareness regarding Smart Pharmaceutical Packaging (SPP) in Ireland, the technology is generally seen as beneficial for enhancing medication adherence and managing chronic illnesses. While privacy, cost, and usability issues emerged as major obstacles, functional features like reminders, real-time tracking, and connectivity with healthcare providers were found to be the most valued attributes. 113 valid responses from patients, caregivers, medical professionals, and members of the general public were obtained from a quantitative, cross-sectional survey. An online structured questionnaire was used to gather the data, and Microsoft Excel was used for analysis. While cross-tabulations and correlation analysis looked at subgroup differences and relationships between digital literacy and adoption readiness, descriptive statistics summarized trends in awareness, perceptions, and behavioral intentions.The findings showed a weak but positive correlation between digital literacy and adoption readiness, indicating that digital competence supports uptake but is not the only determinant, and that adoption was strongly motivated by healthcare provider endorsement. Additionally, subgroup analysis revealed that respondents who were digitally literate and healthcare professionals were more receptive to implementing SPP, whereas some patients with chronic illnesses were more cautious even though they were the group most likely to benefit. The study comes to the conclusion that integrating SPP successfully in Ireland necessitates striking a balance between affordability, inclusivity, public trust, and technological usefulness. Targeted awareness campaigns, robust ethical data protection measures, and stakeholder collaboration to guarantee affordable and user-friendly design are examples of practical recommendations. Although generalizability and causal inference are limited by limitations like non-probability sampling and the cross-sectional design, the results offer insightful information about Irish public readiness for digital health innovation.

CHAPTER 1

INTRODUCTION

1.INTRODUCTION

Chronic diseases like diabetes, cardiovascular disease, and asthma account for over 70% of deaths worldwide which continue to place a heavy burden on healthcare systems around the world which necessitate the development of long-term, sustainable patient management strategies (WHO, 2023). Optimizing medication adherence is a national health priority in Ireland because the growing prevalence of chronic conditions has strained the country's already overburdened healthcare resources.

A promising development in smart pharmaceutical packaging (SPP) combines digital technologies like sensors, QR codes, connectivity modules, and mobile app integration. These tools facilitate safe data exchange between patients and healthcare professionals, provide real-time medication intake tracking, and create automated reminders. These features have been found to dramatically increase patient engagement and adherence, particularly for those undergoing intricate treatment plans (Conn *et al.*, 2015; Faisal *et al.*, 2021; Chai *et al.*, 2022)

Smart pharmaceutical packaging (SPP) describes packaging systems that are integrated with sensor technologies, such as RFID tags, temperature or humidity sensors, and time-temperature indicators, to actively monitor, report, and maintain the quality, safety, and traceability of pharmaceutical products both during patient use and throughout the supply chain(Schaefer and Cheung, 2018; Osadchy, 2024). These systems turn traditional drug packaging into smart platforms that can give consumers and medical professionals up-to-date, useful information.

By permitting accurate tracking and verification, SPP can support efficient medication management, increase regulatory compliance, and improve transparency in addition to guaranteeing product integrity (Osadchy, 2024). The "Pharma 4.0" paradigm, which combines data-driven procedures, automation, and networked health systems to enhance patient safety, treatment compliance, and overall healthcare results, is consistent with this kind of digital tool integration with pharmaceutical packaging.

Although technological potential of smart pharmaceutical packaging is widely reported, its public acceptance remains understudied. Technical capabilities, public trust, digital confidence, and perceived ethical integrity are all critical to the success of these digital interventions. SPP adoption in actual healthcare settings may be constrained by obstacles like low digital literacy,

data privacy concerns and surveillance, and usability issues for older adults or marginalized groups (Xie et al., 2021; Dhamanti et al., 2023).

1.1 Purpose of the Study

By examining public awareness, perceptions, and acceptance of smart pharmaceutical packaging among Irish citizens, this study aims to investigate these behavioral and ethical aspects. The study seeks the opinions of people with chronic illnesses, their caregivers, and medical professionals, thereby capturing the perception of those who use and support medication adherence technologies.

The study also aims to discover how much pharmaceutical packaging such as digital ingestion tracking, real-time reminders, and provider connectivity affect users' intentions to explore SPP and adhere to recommended treatments. It also explores how public willingness to interact with such innovations is impacted by ethical issues like data security, privacy, consent, and digital exclusion.

1.2 Background and Context of the Study

Adoption of digital technology is causing a major change in the pharmaceutical industry, leading to Pharma 4.0 which illustrates how data-driven procedures, smart systems, and automation are being incorporated into pharmaceutical and healthcare operations. The advent of Smart Pharmaceutical Packaging (SPP), a type of technologically enhanced drug packaging that incorporates sensors, wireless modules, QR codes, and other digital tools intended to promote treatment adherence and enhance patient engagement, is one result of this shift (Faisal *et al.*, 2021; Pal *et al.*, 2021).

SPP supports healthcare advancements that allow for remote monitoring and therapy personalization. Reminders, ingestion event detection, patient behavior data collection, and real-time information transmission to healthcare providers are all capabilities of these systems (Chai *et al.*, 2022). In an effort to improve these system’s usefulness and security, technologies like blockchain and artificial intelligence are being explored (Xie *et al.*, 2021). In addition to technological efficiency, the objective is to treat chronic diseases in a way that is more cost-effective, responsive, and preventive.

Despite these developments, SPP is not widely recognized by the public. Majority current research concentrates on clinical applications or technological design, disregarding the ways in which patients, caregivers, and medical professionals view these technologies in routine, non-clinical settings (Dhamanti *et al.*, 2023). Particularly for marginalized populations, ethical and usability issues including privacy, surveillance, digital literacy, and technology access are not fully understood. These concerns are particularly pertinent in Ireland due to continuing healthcare digital transformation and enduring digital gaps. There is a significant gap that this study attempts to fill as not many studies have examined how the general public views smart packaging for managing chronic diseases.

1.3 Significance and Justification of the Study

Personalized treatment and medication adherence may be facilitated by smart pharmaceutical packaging (SPP), an emerging field of innovation in digital health. Despite SPP's introduction into healthcare research, majority of the studies that have been done so far have focused on clinical application and technical performance, with little investigation of actual user experiences. In the literature, there is a noticeable lack of perspectives from patients, caregivers, and healthcare professionals, especially in everyday, non-clinical settings (Hui *et al.*, 2020; Chai *et al.*, 2022).

In Ireland, where digital health practices are advancing but empirical evidence on public involvement with tools like SPP is still lacking, the lack of public focused research is particularly pertinent. As of right now, no published research has looked at how Irish people view the advantages and disadvantages of SPP or how adoption is impacted by elements like trust, privacy concerns, and digital competence. By producing data on adoption preparedness, ethical issues, and public opinions in the Irish setting, this study fills that knowledge gap. Its conclusions will be helpful to developers, legislators, and healthcare professionals looking to adopt inclusive, moral, and user-centered digital packaging solutions.

1.4 Objectives

The Irish public's perceptions and interactions with smart pharmaceutical packaging (SPP) for managing chronic diseases are investigated in this study using a quantitative, positivist methodology. SPP technologies are emerging as a promising tool for improving patient outcomes and medication adherence as chronic diseases become more common and healthcare

systems look for creative solutions. But for successful adoption and implementation, it depends not only on technological availability but also on ethical consideration, public trust, and awareness. The main goals are to measure awareness, perceived utility, digital trust, and ethical issues that could affect adoption behavior.

I. **To determine the general public's understanding, awareness, and perceptions of smart pharmaceutical packaging** as a tool for the treatment of chronic illnesses in Ireland.

II. **To examine how smart packaging functional characteristics** (like reminders, data tracking, connectivity etc) affect intention of people with chronic diseases in Ireland to employ these technologies and their adherence to treatment regimens.

III. **To explore the ethical challenges and possible obstacles** associated with the deployment of smart pharmaceutical packaging in Ireland, such as digital literacy, data privacy, and cyber security.

1.5 Research Questions

The following research question are expected to be answered at the study's conclusion:

- How much does the general public currently know and perceive about smart pharmaceutical packaging?
- What impact do SPP's primary functional aspects have on users' intentions to use the technology?
- What practical and ethical issues influence the public's willingness to adopt SPP for managing chronic illnesses?

1.6 Hypothesis

H1: An increased desire to use smart pharmaceutical packaging is positively correlated with a greater degree of understanding and awareness of the technology.

H2: Users' intentions to accept and adopt technology are positively impacted by the perceived usefulness and efficacy of SPP features (such as progress tracking and medication reminders).

H3: The readiness to adopt smart pharmaceutical packaging solutions is negatively correlated with lower levels of digital literacy and greater concerns about data security and privacy.

1.7 Overview of the dissertation

The rest of this dissertation is set up to facilitate an organized investigation of Irish citizen's attitudes and readiness for adoption of smart pharmaceutical packaging. The introduction is followed by a thorough and critical analysis on smart pharmaceutical packaging, digital health technologies, medication adherence, and ethical issues like digital literacy and privacy. This review gives the study's theoretical base and identifies important research gaps. The research design, philosophical perspective on and techniques for gathering and analyzing primary data are described in the methodology section. It contains information on participant selection, ethical issues, the rationale behind the quantitative approach, and the conceptual framework that directs the study.

The primary research findings are presented in the findings and analysis section. Descriptive and inferential statistical analysis are used to examine relationships between perceived utility, public awareness, ethical considerations, and intention to adopt SPP. To give a contextualized interpretation, the results are then contrasted with knowledge from the literature. The dissertation is concluded in the last section, which summarizes the main conclusions and talks about how they may affect future research, healthcare practice, and policy. A brief personal reflection on the research process is also included, along with helpful suggestions and an acknowledgement of the study's limitations. This framework guarantees fact-based progression from defining the research problem to producing conclusions and practical suggestions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Literature Review

The rise in chronic diseases like diabetes, respiratory disorders, and cardiovascular diseases worldwide has put a lot of pressure on healthcare systems to implement technologies that encourage patient involvement and long-term treatment adherence. SPP supports this by using digital tools such as sensors, QR codes, and electronic blister packs to improve medication-taking behavior (Schaefer and Cheung, 2018; Pal *et al.*, 2021). By tracking usage, sending reminders, and transmitting data, these tools promote medication adherence (Izzah *et al.*, 2022).

The successful deployment of smart packaging systems is based upon patient trust, digital literacy, and social preparedness, despite the rapid advancement of its technological capabilities. When it comes to data privacy, consent, and autonomy, public opinion is crucial in determining how health technologies are adopted (Lin-Hi *et al.*, 2024; Yang *et al.*, 2025). Due to concerns about surveillance, complicated interfaces, or ambiguity regarding control of health data, people may be reluctant to use SPP (Pal *et al.*, 2021). Older adults, those with low digital literacy, and several chronic conditions commonly represented in Ireland's healthcare face difficulties (Quinlan, M. & Priyadarshini, A., 2016).

Although e-prescriptions, remote monitoring, and mobile health apps have demonstrated Ireland's increasing commitment to digital health, empirical research examining public awareness, digital trust, and behavioral readiness for the adoption of smart pharmaceutical packaging technologies in the Irish context is conspicuously lacking. The majority of current research focuses on the effectiveness of technology or its pilot use in clinical settings, rather than the opinions of the general public or patients (Pal *et al.*, 2021; Izzah *et al.*, 2022)

The four interconnected domains of this literature review are (1) the technological role and development of SPP, (2) public awareness and digital trust, (3) the impact of smart packaging features on medication adherence, and (4) the ethical and social implications of adoption. It critically examines the current academic discourse surrounding smart pharmaceutical packaging. The need for population-level insights is highlighted, along with conceptual and empirical gaps in Irish healthcare research. This review serves as the basis for the current study, which examines how the general public in Ireland views smart pharmaceutical packaging and the preparedness of people with chronic illnesses to use this technology.

2.2 Scope and Focus of Literature

Models like the Technology Acceptance Model (TAM), which explains user acceptance based on perceived usefulness and ease of use, and the Unified Theory of Acceptance and Use of Technology (UTAUT), which expands on TAM by including factors like social influence and facilitating conditions, are frequently used in behavioral and adoption-focused research to evaluate perceived usefulness, ease of use, and intention to adopt digital health tools, particularly among older adults (Yang *et al.*, 2025).

Concerns about privacy, data control, and digital exclusion are among the ethical issues raised by a growing body of literature on the subject of digital health tools (Schaefer and Cheung, 2018; Lin-Hi *et al.*, 2024). Although these concerns are particularly pertinent to vulnerable populations, they are rarely discussed in relation to smart packaging. In light of this review, the literature is organized around four main themes: Smart pharmaceutical packaging's operation and development, public perceptions and digital trust, packaging feature's impact on adherence and practical, ethical, and adoption hurdles.

2.3 Smart Pharmaceutical Packaging in Healthcare System

SPP shifts from passive to digitally integrated packaging for enhanced medical adherence. There is evidence that SPP can lower non-adherence, especially in patients with chronic illness with complex and intricate treatment plans (Izzah *et al.*, 2022). Electronic packaging systems have shown that they can securely record adherence data for clinician review, identify missed doses, and notify users with visual or auditory cues. Particularly when combined with cloud-based monitoring platforms or mobile health applications, these features enable more individualized care, earlier interventions, and better health outcomes (Pal *et al.*, 2021).

This evolution reflects a more integrated medication support system. SPP tools often provide reminders and monitor dosage schedules to support adherence. SPP is becoming a more desirable choice for long-term care due to its potential to lower hospital readmissions and enhance the management of chronic diseases. Future studies and pilot projects must assess cost-benefit results, system integration, patient satisfaction, and clinical efficacy in regional settings like the Irish healthcare system. Building on the foundational discussion of technological capabilities, we now explore how these innovations are perceived and trusted by the public.

2.4 Public Perceptions and Digital Trust in Smart Packaging

Adoption of any digital health innovation, including smart pharmaceutical packaging (SPP), is heavily influenced by public opinion. The general public's knowledge and comprehension of SPP are still lacking, despite technological advancements. Most people are unaware of existence of packaging that can share data to healthcare providers, remind medications, or monitor medication adherence (Pal *et al.*, 2021; Izzah *et al.*, 2022). Adoption is severely hindered by this knowledge gap, particularly when the technology demands behavioral shift and confidence in digital systems.

Research indicates that the adoption of health technology is heavily influenced by digital trust, which is people's willingness to rely on digital systems for delicate tasks (Yang *et al.*, 2025). Perceptions of control, transparency, and data privacy all influence trust in the context of SPP. Regardless of the technology's possible health benefits, users are less likely to use it due to data privacy concerns (Lin-Hi *et al.*, 2024). Also, adoption intentions rise when people comprehend the technology's operation and are comforted by data security and supervision (Schaefer and Cheung, 2018).

Public perception is also greatly influenced by digital literacy and health. People who are comfortable with digital tools are more likely to accept smart packaging as its unfamiliarity may cause alarming effect (Quinlan, M. & Priyadarshini, A., 2016). This is particularly important in Ireland, where access to digital health literacy resources may be restricted for lower socioeconomic groups, older adults, and those living in rural areas. In the absence of focused education or engagement tactics, these groups run the risk of losing out on SPP's advantages, which could broaden the digital divide.

Countries like the Netherlands have demonstrated practical integration of electronic medication monitoring tools. In one clinical study, smart pill containers equipped with MEMS were used alongside traditional pill counts to evaluate adherence in patients with hypertension, providing a more precise and consistent tracking method (Van Onzenoort *et al.*, 2010). A broader systematic review across European contexts also found that feedback from electronic monitoring systems significantly enhanced medication-taking behavior in chronic illness management, even if the impact on clinical outcomes varied (Van Heuckelum *et al.*, 2017). These examples reflect how established digital infrastructure and coordinated healthcare

strategies have supported early adoption of smart packaging technologies in some European health systems.

Crucially, digital trust is both institutional and technical. Users may be concerned about government organizations or pharmaceutical companies accessing their adherence data for commercial misuse, surveillance, or judgment (Pal *et al.*, 2021).These issues can be reduced and acceptability can be increased with the assistance of dependable healthcare providers (like community pharmacists), transparent communication, and explicit consent procedures.

Perception is also influenced by design as packaging that appears unduly medicalized, complex, or digital may discourage certain users. Users with low digital literacy may be encouraged to adopt designs that are visually accessible, easy to understand, and with minimal steps. Apps for medication adherence tends to be successful when co-designed with users, according to (Quinlan, M. & Priyadarshini, A., 2016), which suggests that similar participatory design techniques might increase SPP receptivity.

Global comparisons can provide valuable insights. Smart health tool adoption has been smooth in nations with higher digital penetration and health technology integration, like Sweden and the Netherlands, in part because of higher baseline levels of digital literacy and infrastructure (Izzah *et al.*, 2022). Comparatively, Ireland is still creating national strategies for integrating digital health, so it is important to investigate the local attitudes, access, and education influence preparedness for SPP and other technologies. Pharmacist-led mobile adherence tools are the subject of studies like (Quinlan, M. & Priyadarshini, A., 2016) but little is known about how Irish patients or caregivers view packaging-based interventions.

This is a significant knowledge gap, especially in light of the nation's growing investments in digital health infrastructure. Although issues like awareness, trust, and usability are highlighted by public perceptions, theoretical frameworks like TAM and UTAUT offer organized methods to explain how these perceptions affect adoption behaviors.

2.5 Technology Acceptance and Adherence practices

SPP technologies incorporate adherence support right into the packaging to change health-related behaviors. Features like automated dose logging, visual or auditory reminders, and real-time feedback help increase adherence to treatment plans. These characteristics have been

demonstrated to dramatically increase adherence, especially in older adults and those with complicated medication regimens (Izzah *et al.*, 2022). The significance of user-centered design is underscored by the fact that different users have different preferences, with some finding connectivity and reminders valuable while others may find them intrusive or unnecessary (Pal *et al.*, 2021).

Smart packaging may serve as a monitor and a prompt for behavior modification, encouraging the development of routines and accountability. However, the feeling of being watched can cause discomfort or resistance, particularly when healthcare providers can see the adherence data. It was observed that when users maintain control over their data and the system encourages their health behavior rather than controls it, they are more likely to embrace these technologies.

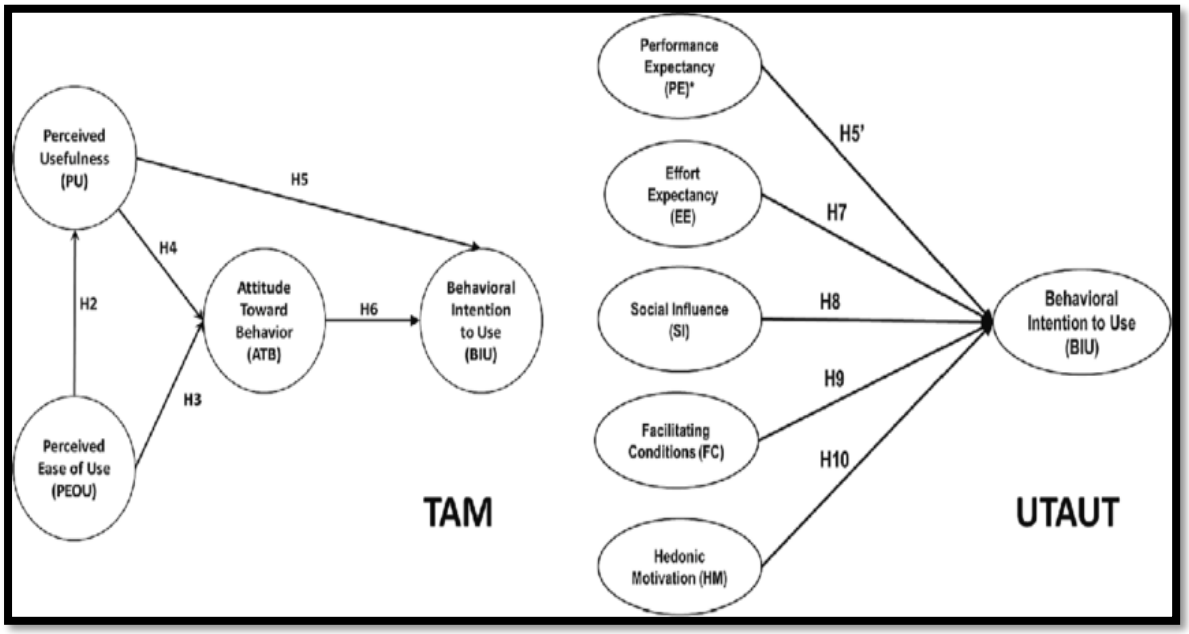

Figure 1. Conceptual model of TAM and UTAUT (Widyanti et al., 2024)

Acceptance is frequently more strongly influenced by perceived ease of use than by the actual complexity of the technology. Regardless of the advantages, users may stop using the packaging if it is too large, challenging to open, or technologically overwhelming (Schaefer and Cheung, 2018). Successful use is strongly associated with digital confidence, particularly

in older adults, and interventions that promote digital literacy may be required to guarantee equitable access (Quinlan, M. & Priyadarshini, A., 2016).

The role of healthcare providers is another vital factor. When a trusted clinician or pharmacist recommends SPP and provides clear instructions on how to use the technology, patients are more likely to follow through on the recommendation (Yang *et al.*, 2025). This emphasizes how crucial it is to rely on professional assistance and education with technological innovation. Behavioral intention of caregivers and patients towards SPP has not yet been studied, despite the fact that international studies on technology acceptance across a range of health tools has been done. Given the increasing adoption of digital health tactics in Ireland's chronic disease management policies, this is a noteworthy disparity.

Despite their initial novelty, many patients say they are willing to try digital adherence tools but discontinue to use them. Lack of continuous support, perceived intrusiveness, and technological fatigue can be the main causes (Pal *et al.*, 2021). It is important to differentiate between short-term engagement and long-term behavioral integration. Even carefully planned systems may not have the desired effect if they are not continuously reinforced or customized. Perceived necessity and health status are also strongly related to user motivation. Patients who have stable or asymptomatic chronic conditions may disregard adherence support tools and deprioritize their medication. On the other hand, SPP might actually be beneficial for people with complicated regimens or a history of missed doses. This emphasizes the need for targeted deployment adapted to the risk, need, and readiness of each individual user rather than a one-size-fits-all approach.

In conclusion, smart pharmaceutical packaging features that improve adherence only work when users find them to be empowering, understandable, and acceptable. Designing SPP systems that satisfy user needs and promote long-term adoption requires an understanding of behavioral intention using well-known models such as TAM and UTAUT. It will take a human-centered strategy that incorporates not only technical functionality but also psychological support, education, and policy alignment to close the gap between interest and sustained use. In parallel with user engagement, ethical and societal considerations present additional challenges and responsibilities in SPP implementation.

2.6 Ethical and Social Implications of Smart Packaging

Many ethical and social issues are brought up by the growing use of smart pharmaceutical packaging (SPP), especially those related to data privacy, surveillance, accessibility, and digital equity. Irrespective of their clinical and behavioral advantages, their use must be evaluated to protect user's autonomy and dignity.

Data privacy is one of the most important ethical issues with SPP, especially in context of European laws like GDPR. When integrated with healthcare platforms, SPP systems can collect time-stamped data about medication use that could be connected to private medical records. It runs the risk of breaking fundamental data protection guidelines and eroding user confidence if this data is kept, sent, or examined without clear consent (Lin-Hi *et al.*, 2024). Even though many manufacturers claim they use secure cloud-based environments, the average user may not understand how encryption, access controls, and data retention policies are actually implemented in practice.

Informed consent is another concern. In contrast to one-time data collection methods, smart packaging entails continuous behavioral monitoring. If consent is made via complicated or poorly explained terms and conditions, patients might not fully understand what data is being collected or how it will be used (Schaefer and Cheung, 2018). Clear, understandable data flow explanation and patient ability to discontinue participation at any moment without affecting their treatment are necessary for true ethical engagement. By guaranteeing that patients actively participate in decisions regarding their care technology, this is consistent with ethical principles of autonomy and respect for persons.

The possibility of surveillance and the possible loss of individual autonomy are further concerns. When data is automatically shared with caregivers or healthcare providers, smart packaging may make users feel watched which is quite invasive, but it can also be clinically helpful in identifying non-adherence or in supporting early intervention. According to studies, users feel more at ease when they have discretion over their data access (Lin-Hi *et al.*, 2024). It is crucial to carefully balance the need for help and control, especially when dealing with vulnerable groups like the elderly, people with cognitive impairments, or people dealing with mental health issues.

Ethical implementation necessitates an obligation to accessibility and inclusivity in addition to privacy and surveillance. People with different levels of cognitive function, physical ability,

and health literacy should be able to use SPP. Smart packaging may leave out people who need adherence support the most if it calls for complicated app pairing, frequent charging, or challenging-to-open containers. According to Quinlan, M. & Priyadarshini, A., 2016, digital health tools should be made with a broad spectrum of users in mind, including those who are older, non-native speakers, or have visual or motor impairments. Ethically responsible design takes into account the end user's usability and empowerment in addition to being technically feasible.

Socioeconomic and educational factors, such as exposure to health technology education, proficiency with digital tools, or the ability to buy internet-enabled devices, may also influence access to smart packaging. SPP runs the risk of exacerbated current health disparities and expanding the digital divide if it is implemented without addressing these constraints. Furthermore, if there are no reimbursement policies in place to offset these costs, the price of smart packaging and associated services may discourage patients with low incomes from using them (Pal *et al.*, 2021).

Professional ethics are also affected, especially for pharmacists and other healthcare professionals who might be responsible for putting SPP systems in place and keeping a tab on them. These practitioners have to strike a balance between the ethical duty to preserve patient autonomy and confidentiality and the clinical advantages of adherence data. To help providers navigate this new landscape and to ensure that digital tools are used to support patients rather than to coerce or punish them, ethical training might be necessary.

Transparency and continuous patient feedback are also essential components of the ethical application of SPP. User concerns and ethical frameworks may change as technologies advances. Constant user involvement, whether via questionnaires, feedback loops, or patient advisory panels, ensures that ethical issues are at the forefront of the entire technology lifecycle, from development to implementation and assessment.

In conclusion, although smart pharmaceutical packaging has the potential to enhance medication adherence and health outcomes, its ethical and social implications cannot be disregarded. In order to address issues with data privacy, consent, surveillance, accessibility, and equity, there is a need for responsive governance, inclusive practices, and transparent

design. Despite the potential and considerations discussed, several real-world barriers complicate the implementation of SPP in Ireland.

2.7 Barriers to Implementing Smart Pharmaceutical Packaging in Ireland

Smart pharmaceutical packaging (SPP) has the potential to enhance chronic disease management and medication adherence, but an array of obstacles prevents its widespread adoption, especially in the Irish healthcare system. The technological complexity and the infrastructure it need to be integrated into is reflected in these difficulties.

The price is one of the most obvious obstacles. Compared to traditional packaging, smart packaging technologies are usually much more expensive due to the need for specialized materials, sensors, and digital integration platforms (Pal *et al.*, 2021). Many patients may not be able to access SPP if reimbursement plans or participation in public procurement procedures are not in place. This issue is particularly relevant in Ireland's cost-conscious public health system. Despite the fact that international trials have shown better adherence outcomes, few economic evaluations have examined whether these advantages eventually result in lower healthcare costs (Schaefer and Cheung, 2018).

In addition to affordability, interoperability and infrastructure poses hurdles. Numerous smart packaging options depend on reliable internet connections, smartphone apps, and Bluetooth pairing—conditions that are not accessible for all patients. Another issue as Ireland shifts to integrated digital health platforms is compatibility with current electronic health records (EHRs). The clinical utility of SPP may be limited in the absence of smooth interoperability since data produced by the technology might not be easily available or usable by medical professionals (Lin-Hi *et al.*, 2024).

Institutional resistance is also connected to policy prioritization and system readiness. Although Ireland's healthcare strategy is increasingly focusing on digital health, smart packaging has not yet been extensively integrated into national chronic disease management plans. Adoption in public settings is hampered by the lack of policy guidance on clinical workflows, implementation, or procurement. Without unambiguous professional or regulatory support, health systems might be hesitant to invest in new technologies (Pal *et al.*, 2021).

Professional resistance is another major obstacle. SPP adoption face resistance from doctors and pharmacists due to disruption of workflow, lack of training, or lack of clarity of their roles in tracking adherence data. For instance, workload of pharmacist may increase if they have to follow up with patients or modify their counseling techniques due to real-time data from SPP. Healthcare professionals may not adopt these roles unless they are well equipped and backed by compensation and training (Quinlan, M. & Priyadarshini, A., 2016).

Also, patient-level resistance needs to be taken into account. Smart packaging, like other digital health interventions, is more likely to be rejected by users due to unfamiliarity with technology and privacy concerns. Some patients find features like cloud connectivity or automated alerts overwhelming or intrusive, but many patients appreciate the goal of SPP, according to (Izzah *et al.*, 2022). Patient hesitancy could severely restrict uptake in Ireland, where digital confidence varies greatly by age and region, especially among older adults and those managing chronic conditions.

Additionally, smart packaging competes with preexisting adherence aids that patients and clinicians are already accustomed to using, like SMS reminders, pill organizers, and smartphone apps. There may be doubts about whether SPP provides enough extra value to support its adoption because these tools are frequently less expensive, easier to use, and more well-understood (Pal *et al.*, 2021). Stakeholders must effectively communicate SPP's comparative advantages, such as its real-time feedback capabilities and integration with physical medication handling for implementation in order to be successful.

Lastly, the lack of implementation studies tailored to Ireland raises questions about how SPP will function locally. The majority of previous studies have been carried out in controlled or foreign environments, providing little understanding of the real-world difficulties facing the Irish healthcare system. It is challenging to create accurate estimates of efficacy, cost, or acceptance in Irish healthcare settings without pilot programs or demonstration projects. In conclusion, there are a number of obstacles to the adoption of smart pharmaceutical packaging in Ireland, related to infrastructure, cost, user acceptance, and system readiness. In order to overcome these obstacles, united efforts spanning policy, practice, and patient education will be needed, backed by research and data unique to Ireland that will direct scalable, long-term integration.

With the thematic insights covered, we now evaluate the literature to identify research gaps that inform the current study.

2.8 Evaluating Existing Literature and Identifying Gaps

Usability studies, clinical trials, and adherence research are revealing strong technical and behavioral insights in the rapidly evolving field of smart pharmaceutical packaging (SPP). Prior studies have mostly focused on the technical efficacy of packaging features like e-blister packs, real-time dose tracking, and reminder systems that may enhance adherence across patient groups ((Izzah *et al.*, 2022). These studies provide a solid foundation for understanding the potential role of SPP in managing chronic conditions.

However, there is a crucial gap in the finding's generalizability. Numerous studies have been carried out in pilot settings that are controlled or small-scale, frequently with high user support and little variation in patient profiles. This raises questions regarding practicality, especially in public health systems where there is a high degree of variation in digital access, literacy, and system integration (Schaefer and Cheung, 2018). Additionally, there is currently little data on how behavioral models like TAM and UTAUT specifically relate to smart packaging over time, despite the fact that these models are used to understand patient interaction with health technologies (Yang *et al.*, 2025).

Crucially, there is not enough research that is unique to Ireland. According to (Quinlan, M. & Priyadarshini, A., 2016), no peer-reviewed studies have looked at Irish public attitudes, digital readiness, or professional perspectives on SPP, despite the fact that international literature emphasizes the significance of trust, usability, and institutional endorsement in successful adoption. This is a notable absence, given Ireland's distinct digital infrastructure environment, its hybrid public-private healthcare system, and the existence of vulnerable groups with lower levels of digital confidence. Questions concerning reimbursement models, policy integration, and the role of general practitioners and pharmacists in promoting the technology are also raised by the lack of national implementation studies.

Furthermore, while ethical concerns like user autonomy, consent, and data privacy are commonly recognized, they are not adequately examined in long-term settings. Although there are frameworks for these problems, little is known about their real-world applications and user feedback (Lin-Hi *et al.*, 2024). Instead of being co-designed with patients, current research is

frequently technology-driven, which restricts its capacity to represent end user's values and concerns. In order to fill these gaps, this dissertation examines adoption readiness, digital trust, and public perceptions in the Irish context with a particular focus on managing chronic diseases. By doing this, it hopes to offer fresh perspectives on the moral, social, and structural essentials for the adoption of SPP in an equitable manner. Future research in the Irish context should prioritize co-design initiatives, public consultations, and pilot studies that reflect real-world usage patterns and diverse patient experiences.

2.9 Conclusion

The research on smart pharmaceutical packaging (SPP) shows great potential for improving medication compliance, especially when it comes to treating chronic conditions. Modern technological advancements like e-blister packs, tracking enabled by QR codes, integration with mobile apps, and real-time dose monitoring provide workable answers to persistent adherence issues. Research substantiates the idea that these tools can improve patient behavior, strengthen treatment regimens, and enable prompt clinical interventions (Pal *et al.*, 2021; Izzah *et al.*, 2022).

While theoretical frameworks such as TAM and UTAUT provide useful insights into behavioral intention and long-term technology use, especially among older adults, in digital healthcare settings (Yang *et al.*, 2025).SPP integration in the Irish healthcare system offers special opportunities and challenges. Despite Ireland's growing interest in digital health, little is known about smart packaging, and no peer-reviewed research has examined how the Irish public feels about SPP to date. The ongoing expansion of digital health infrastructure and national efforts to improve the outcomes of chronic diseases make this gap especially crucial. By examining public attitudes, digital trust, and preparedness to embrace smart pharmaceutical packaging in Ireland, this dissertation aims to fill these gaps, with a particular emphasis on people with chronic illnesses. Through determining the behavioral, ethical, and social elements that influence acceptance, the study will offer context-specific knowledge that can guide future initiatives in education, design, and policy.

In conclusion, even though smart pharmaceutical packaging has a solid technical basis, its practical viability hinges on larger societal and healthcare factors. To ensure that SPP can fulfill its potential as a significant, equitable, and long-lasting tool in contemporary healthcare, it is

imperative to comprehend these dynamics, particularly from an Irish perspective. This research ultimately seeks to answer how public trust, ethical concerns, and digital readiness affect the adoption of smart pharmaceutical packaging in Ireland, with implications for policy, design, and practice. These trends show that factors like data security, public trust, and healthcare integration continue to be crucial even in the face of technological advancements. The methodological focus of this study is directly influenced by these gaps.

CHAPTER 3

RESEARCH METHODOLOGY

3. RESEARCH METHODOLOGY

This chapter describes the research approach taken to investigate how the Irish society perceives Smart Pharmaceutical Packaging (SPP), specifically with regard to managing chronic illnesses. With features like digital reminders, real-time dose tracking, and secure data sharing with healthcare providers, the study explores how people perceive, trust, and are inclined to use these technologies. The study focuses on the digital readiness, ethical considerations, and behavioral intentions of patients, caregivers, and medical professionals.

The Research Onion Model was put forth by Saunders, Thornhill, and Lewis (2009) as a thorough framework for developing a research technique. With each layer representing a step or element of the study design, this approach represents the numerous levels of the research process as an onion. Following Saunders et al.'s (2023) research onion, the chapter begins by describing the philosophical basis of the study before discussing the research design, data collection, and analysis. It describes the survey's design and testing procedures, the participant selection procedure, and the analytical methods used to interpret the results. Informed consent, privacy, and data protection are among the ethical issues that are covered. Eventually the conceptual framework that connects the literature review to the research methodology and analysis is presented based on well-established models of technology adoption.

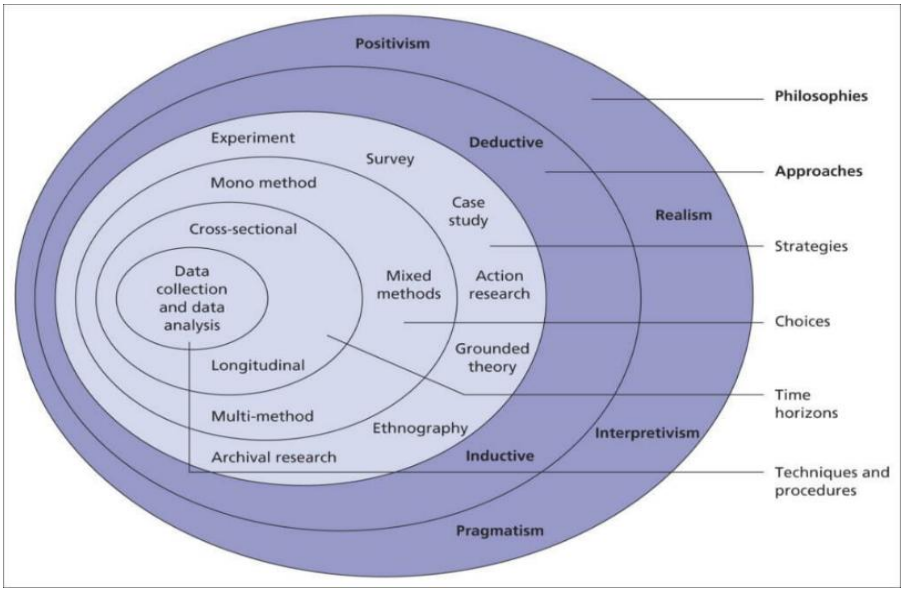

Figure 2. Research Onion Model (Saunders et al. 2019)

3.1 Research Philosophy

The positivist research philosophy, which maintains that the best way to learn is to observe and measure objective reality, is adopted in this study. According to positivism, social phenomena can be investigated using structured methodologies and empirical data to test hypotheses, just like the natural sciences. It encourages the use of quantitative methods, like surveys, to find patterns and connections that apply to broader populations. The study aligns the philosophical layer of (Saunders *et al.*, 2023) research onion by taking a positivist stance, which lays the foundation for the following strategy and design.

Alternative philosophies were less appropriate for the research. Since this study aims to identify measurable patterns, interpretivism which emphasizes subjective meaning was not used. As the design is theory-driven, pragmatism which emphasizes practical results was inappropriate. The current study looks at observable perceptions rather than more profound causal structures hence realism which emphasizes underlying mechanisms was not chosen (Creswell, J.W. and Creswell, J.D., 2017; Saunders *et al.*, 2023).

The current study attempts to assess public attitudes, digital trust, and adoption intentions regarding smart pharmaceutical packaging (SPP) is suited for this philosophy. Without depending on insignificant interpretation, these variables can be operationalized and statistically investigated. To find significant patterns, a positivist approach makes it possible to employ validated tools and standardized data analysis techniques.

The Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Acceptance Model (TAM), which were both created and evaluated using positivist, quantitative methodologies, provide additional support for the study (Davis, 1989; Venkatesh *et al.*, 2003a). To forecast user behavior, these models measure concepts like perceived utility, usability, and social influence. This study guarantees philosophical alignment with its theoretical models, methodological instruments, and analytical approaches by taking a positivist position. The study acknowledges that total objectivity is rarely possible in social research, despite its positivist foundation. Thus, it exhibits a post-positivist stance, recognizing possible drawbacks while continuing to use systematic, quantitative techniques to reduce bias and enhance validity.

3.2 Research Design and Approach

The methodology used in this study is deductive, starting with established theories and testing them against empirical data (Creswell, J.W. and Creswell, J.D., 2017). In particular, it evaluates elements that affect the public's acceptance of smart pharmaceutical packaging (SPP) using the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT). The research aims to validate theoretical constructs through empirical evidence, such as perceived usefulness, digital trust, and intention to adopt, a deductive approach is appropriate.

A quantitative, cross-sectional survey design is used in the study, enabling data to be gathered from a large number of participants at one time. This design works well for finding patterns and connections between variables, particularly in technology and health studies (Saunders *et al.*, 2023). Additionally, it facilitates statistical analysis, allowing for the investigation of predictive relationships and correlations between variables like behavioral intention and digital literacy. A quantitative, cross-sectional survey design was adopted because it allowed for effective data collection given the study's time and resource constraints and was consistent with the goal of the study. In order to capture attitudes and intentions within a specified timeframe, the study used a cross-sectional time horizon and a quantitative mono-method approach.

Because it would take longer tracking to see changes, a longitudinal design was not preferred as it was outside the scope of the study. The cross-sectional approach has limitations, such as only offering a snapshot in time, which makes it impossible to record how perceptions change over time, and limiting causal inference because observed relationships cannot validate cause-and-effect.

A structured questionnaire was chosen for gathering data. Due to their anonymity, scalability, and standardization, surveys are frequently employed in technology adoption research (Venkatesh *et al.*, 2003a). In addition, they are ideal for gathering quantitative information that captures the perspectives and experiences of a different populations, such as patients, caregivers, and healthcare workers. The questionnaire's design was influenced by earlier research on medication adherence and digital health interventions (Faisal *et al.*, 2021; Izzah *et al.*, 2022).

3.3 Sampling Strategy

- Sampling Methods: The study uses a non-probability sampling approach, specifically convenience and snowball sampling. Convenience and snowball sampling, two non-probability sampling techniques, are used in this study. This decision was pragmatic because it made it possible to promptly reach participants via online platforms, patient groups, and pharmacies. Reduced generalizability is the trade-off, as the results should be viewed as exploratory insights into the sampled groups rather than being presumed to be representative of the larger population (Saunders et al., 2023). Convenience sampling made it possible to quickly reach participants who were easily accessible, while snowballing increased the sample's diversity by reaching harder-to-reach people like patients with chronic illnesses and caregivers.

  Convenience sampling was applied by distributing the survey through accessible channels such as pharmacies, patient support groups, and digital platforms. Snowball sampling involved encouraging initial respondents to share the survey within their networks, allowing the sample to grow organically. This approach was chosen for its practicality, especially when targeting groups like patients with chronic conditions and caregivers, who may be difficult to reach through random sampling. While non-probability sampling limits the ability to generalize findings to the wider population, it is widely accepted in exploratory research, particularly in healthcare and technology contexts where fast, focused access to participants is needed (Saunders et al., 2019).

- Sample Size: The study's target sample size was between 100 and 150 participants, as determined by Green's (1991) multiple regression analysis guideline: $N > 104 + k$ (where k is the number of predictors). Within this range, supervisory recommendations are followed while statistical power and practical feasibility are balanced. This sample size is sufficient for trend identification and subgroup comparisons (e.g., by role, age, or digital literacy). For thorough quantitative analysis and exploratory insights, this range is adequate, even though larger samples provide greater generalizability (Bryman, 2016b).

3.4 Participant Criteria and Recruitment

- Target Participants: People who are either directly or indirectly involved in managing and using medications were the focus of this study. These included

healthcare professionals like pharmacists, nurses, and care home staff; patients with long-term conditions like diabetes, asthma, or cardiovascular disease; and informal caregivers who help with medication routines.

People who regularly use health-related technologies and are digitally literate were also included. Because they are the most likely users and stakeholders of smart pharmaceutical packaging (SPP), these groups were chosen.A wide range of age groups, occupations, and degrees of digital literacy were also targeted by the study. This diversity was crucial to achieving the research objective of gathering diverse viewpoints on digital trust and adoption readiness, guaranteeing that findings represent the experiences of multiple stakeholder groups rather than just one.

- Inclusion Criteria: The following inclusion requirements were used to make sure that participants were appropriate and capable of making a significant contribution to the study: they had to be at least eighteen years old, live in Ireland, and be communicate in English. Before beginning the survey, participants had to give their informed consent and have either professional or personal experience managing medications. These requirements made sure that information was gathered from people who could fairly assess SPP's acceptability and utility.

- Recruitment Process: Both digital and community-based outreach were used to find participants. Online recruitment entailed disseminating the survey through newsletters from healthcare organizations, chronic illness support forums, and social media platforms. Putting QR-coded flyers in pharmacies, neighborhood clinics, and community centers was one method of offline recruitment. Additionally, snowball sampling was promoted, asking respondents to forward the survey to other members of their network who fit the inclusion requirements.
  A participant information leaflet outlining the goals of the study, their rights, and data protection protocols was given to each participant. Using two screening questions at the start of the survey, consent was digitally obtained. By focusing on a range of demographic groups across age, occupation, and digital literacy levels, diversity was promoted. Since participation was completely voluntary and no

personally identifiable information was gathered, confidentiality and ethical compliance were guaranteed.

3.5 Survey Design and Pilot Testing

The main instrument for gathering data was an online, structured questionnaire. Smart pharmaceutical packaging (SPP) awareness, perceptions, and behavioral intentions in Ireland were the main goals of the survey. Important concepts from the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Acceptance Model (TAM) served as the foundation for its structure. These included perceived utility, usability, digital trust, and adoption readiness (Davis, 1989; Venkatesh *et al.*, 2003a). Such models offered a theoretical basis for comprehending how people assess and decide to use new technologies.

There were five primary sections to the questionnaire. In accordance with GDPR regulations, the first section presented the study and used two checkbox confirmations to obtain informed consent. Demographic information, including age, gender, occupation, education, and digital literacy, was gathered in the second section. The third assessed participants' knowledge and opinions about SPP, including its perceived advantages and applicability to the treatment of chronic illnesses. Participants were asked to rate their likelihood of adopting the technology and their level of confidence in features like data privacy and reminder systems in the fourth section, which examined behavioral intention and digital trust. The last section covered perceived obstacles and ethical issues like data misuse, system dependability, and usability issues.

Likert scales with five points, from "strongly disagree" to "strongly agree," were used in the majority of survey items. Google Forms, which offered a user-friendly and GDPR-compliant platform, was used to deliver the questionnaire. Effective data collection, anonymous participation, and secure response handling were all made possible by this format. A comprehensive Participant Information Leaflet (PIL) explaining the goal of the study, the participants' rights, and the intended use of their data was given to them at the beginning of the survey.

Eight members of the target population participated in a pilot test to confirm the survey's usability and clarity. Patients, unpaid caregivers, and medical professionals made up this group. Feedback regarding the form's technical experience, question flow, and language clarity was

requested from the participants. Based on this feedback, a few minor changes were made, such as rewording unclear items, providing definitions for terms like "smart packaging," and enhancing the questions' logical sequence. The survey's final version was made understandable and able to collect consistent, dependable responses thanks to the pilot. The pilot's small sample size (n=8) might not accurately reflect the target population, which is one of its limitations. Although it was helpful in pointing out problems with usability and clarity, it might not have fully represented the range of participant perspectives. Pilot data is not included in main dataset.

In order to improve validity and refine instruments, pilot testing is an essential part of survey research. In this instance, it improved the tool's internal consistency and face validity, guaranteeing that participants understood the questions and gave insightful answers (Bryman, 2016b; Saunders *et al.*, 2023). As a result, the finished survey instrument was in a good position to generate excellent quantitative data that matched the study's goals. The below Table1. Shows operationalisation of TAM and UTAUT constructs in survey items.

Construct (TAM / UTAUT)	Operational definition in the Study
Perceived Usefulness	The degree to which SPP enhances medication administration
Ease of Use	The extent to which SPP is easy to use
Digital Trust	Trust in SPP data security and privacy
Behavioural Intention	Willingness to adopt SPP

Table 1. Operationalisation of TAM and UTAUT Constructs in Survey Items

3.6 Data Collection

An online survey hosted on Google Forms, a safe and GDPR-compliant platform, was used to collect data over two weeks. The questionnaire link was disseminated via social media, email, and community health organizations, among other platforms. To reach people with little internet exposure, physical flyers with a QR code connected to the survey were also put in participating pharmacies and community centers. The study was able to gather a variety of viewpoints from those involved in medication use and care thanks to this mixed recruitment strategy. By using Google Forms, the possibility of human error or data manipulation was decreased because automatic data recording and secure storage were guaranteed. The survey's format increased response rates and decreased dropout rates by allowing respondents to finish it whenever it was most convenient for them.

Response bias is a possible drawback, since despite efforts to recruit through both digital and community channels, people who are more proficient in technology might be more inclined to participate. When interpreting the results, it should be taken into account the possibility that the sample represents a higher level of digital readiness than the general population.

To guarantee informed participation, participants were shown the Participant Information Leaflet (PIL) before answering two consent questions. No identifying information, such as names, email addresses, or IP addresses, was gathered from the anonymous responses. After removing any duplicate or incomplete responses before analysis, a total of [insert final number of valid responses] responses were received. A standardized process was used for data collection, guaranteeing uniformity for all participants. To help detect technical problems or abnormally short completion times, all responses were timestamped. Effective preparation for statistical analysis was made possible by the use of an online platform that made exporting data into spreadsheet software simple.

3.7 Data Analysis Plan:

For preparation and analysis, the survey responses were exported from Google Forms into Microsoft Excel. Accessibility, the ability to handle structured datasets, and the ability to produce descriptive statistics and visuals appropriate for survey-based research were the main

reasons Excel was selected as data analysis tool. The dataset was cleaned up before analysis by eliminating duplicate or incomplete responses. Google forms in which participants gave their complete informed consent were only retained. Numerical coding was used to enable systematic analysis of categorical data, such as Likert-scale items (Creswell, J.W. and Creswell, J.D., 2017)

There were two phases to the analysis. In order to summarize participant demographics and response patterns across constructs like awareness, perceived usefulness, ease of use, digital trust, and adoption readiness, descriptive statistics (frequencies, percentages, means, and standard deviations) were first developed. For interpretation and ensuring clarity, graphic outputs like frequency tables, pie charts, and bar charts were employed(Pallant, 2020; Saunders *et al.*, 2023).

Second, cross-tabulations were used to perform bivariate analysis. For instance, correlations between attitudinal measures (like trust and adoption readiness) and demographic characteristics (like age, gender, and digital literacy) were investigated. Excel pivot tables were used to find trends, participants of which age group had greater digital trust or if adoption intentions were different among healthcare professionals than among patients and caregivers. These actions are in line with social science research guidelines, which state that cross-tabulation sheds light on relationships between independent and dependent variables without considering causality (Creswell, J.W. and Creswell, J.D., 2017; Field, A.P, 2018).

Excel was modified to follow the SPSS principles outlined in Pallant (2020) and Field (2018) because the statistical logic (such as calculating frequencies, means, or cross-tabulations) is the same regardless of the software. Excel was specifically chosen as the analysis tool because of the study's emphasis on descriptive and exploratory statistical methods as well as the manageable size of the dataset. Despite having fewer features than specialized statistical software like SPSS, Excel was a good fit for the study's objectives, schedule, and available resources.

Lastly, the technological acceptance model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) were the sources of the conceptual framework constructs to which all analyses were explicitly mapped. This improved the findings' validity and coherence

by guaranteeing consistency across the survey design, data interpretation, and theoretical underpinnings.

3.8 Ethical Considerations

After submitting the ethics application and all necessary supporting materials supervisor granted ethical approval for this study. In order to ensure respect for autonomy, privacy, and data integrity, the study was designed in complete accordance with the ethical principles set forth in the Belmont Report and the General Data Protection Regulation (GDPR) (EU 2016/679).

Study participation was completely voluntary. At the start of the survey, the PIL was given to each respondent, outlining the goals of the study, the requirements for participation, the possible risks and rewards, and the intended use of their data. Two required confirmation questions were used to get consent before respondents could continue. Anonymity and confidentiality were guaranteed since no personal identifiers, including names, contact details, or IP addresses, were gathered. Before submitting their answers, participants were made aware that they could leave the study at any moment in order to further reduce risk. The survey's wording avoided bias and pressure by being courteous and neutral. Only the researcher and supervisor had access to the password-protected system where the data was safely stored. In compliance with institutional policy, the data will be erased once the study is over.

Sensitivity to digital literacy levels and trust in digital systems were given priority because the study involved human participants talking about their opinions on healthcare technologies. In accordance with suggestions from academic research ethics guidelines, ethical standards were maintained throughout the study to preserve participant dignity and guarantee responsible conduct (Saunders et al., 2019; Bryman, 2016). Despite the low risk of the study, it is recognized that some participants may experience mild emotional discomfort when talking about their chronic illness and medication regimens. In order to reduce this, the survey was created using polite, neutral language, and respondents were reminded that they could stop participating at any time without facing any repercussions.

3.9 Conceptual Framework

The Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Acceptance Model (TAM) are two well-known models that serve as the foundation for this investigation. According to TAM, perceived utility and usability have the biggest impact on users' adoption of new technologies (Davis, 1989). Additional elements like social influence and enabling circumstances are added by UTAUT (Venkatesh *et al.*, 2003a). These models offer a solid basis for comprehending how people assess smart pharmaceutical packaging (SPP). Awareness, perceived usefulness, ease of use, digital trust, and behavioral intention are important constructs that have been incorporated into this study. The survey questions accurately reflected these, allowing for a systematic examination of the variables affecting adoption. Consistency between the survey design, data analysis, and literature review is guaranteed by the conceptual framework (Figure 3). Additionally, it supports the study's goal of determining the factors that have the biggest impact on user attitudes toward SPP in the context of managing chronic illnesses.

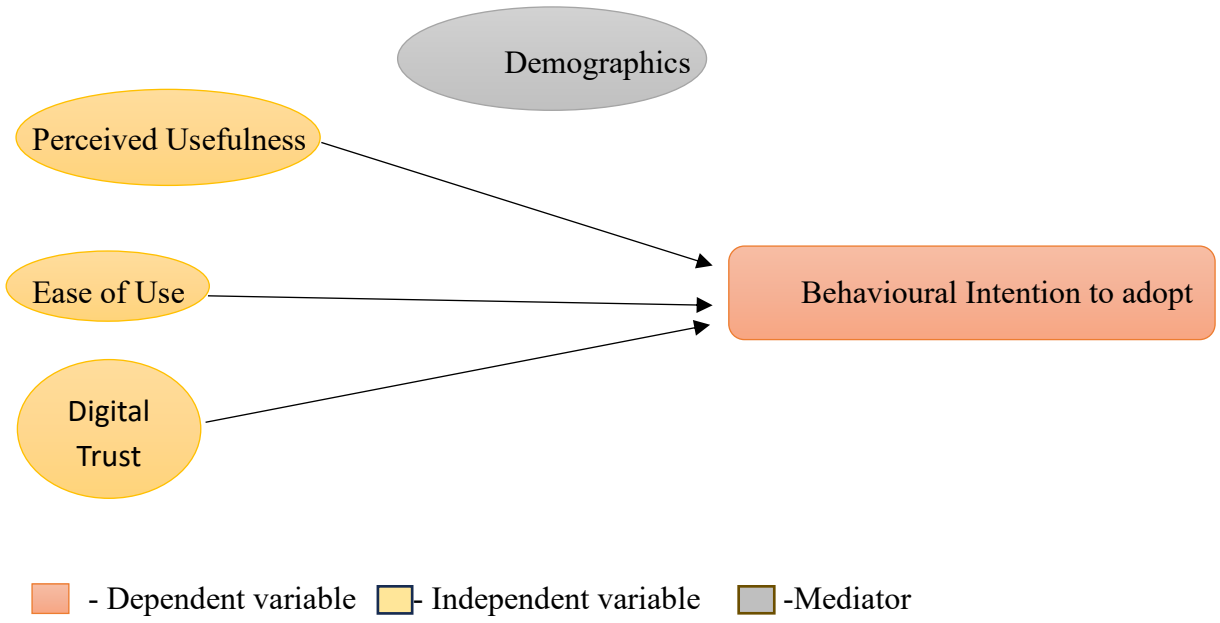

Figure 3. Conceptual Framework: Adoption of Smart Pharmaceutical Packaging

3.10 Conclusion

There are unavoidably trade-offs associated with the methodological decisions made in this study. The cross-sectional design makes it difficult to determine causality or monitor changes over time, and the use of non-probability sampling limits how broadly the results can be applied. Considering the study's scope, timeframe, and resources, these choices were reasonable and appropriate, and they still support the exploratory goal of analyzing Irish public perceptions, digital trust, and adoption readiness of smart pharmaceutical packaging. The results and analysis obtained from the survey data are presented in the upcoming chapter.

CHAPTER 4

FINDINGS AND ANALYSIS

4. FINDINGS AND ANALYSIS

This chapter summarizes the findings of survey that examines the public perception of Smart Pharmaceutical Packaging (SPP) in Ireland. In order to recruit a diverse group of participants, a non-probability sampling strategy combining convenience and snowball techniques was employed. Patients with chronic illnesses, informal caregivers, medical professionals, home care assistants, students, retirees, and members of the general public were all included, which reflected the wide range of stakeholders who might interact with medication technologies in diverse ways.

A total of 160 responses were gathered. Following the application of the consent criteria, 113 valid responses were considered for analysis. In order to enable meaningful comparisons between demographic subgroups, the final sample includes a wide range of age groups, genders, educational backgrounds, occupations, and levels of digital literacy. The study's goals are addressed in the analysis which includes understanding and familiarity with SPP, perceptions of its utility and ease of use, digital trust and privacy issues and behavioral intention to use SPP in managing chronic diseases.

Microsoft Excel was used for the quantitative data analysis. Statistical analytics (cross-tabulations and subgroup comparisons) investigate the connections between demographic features and public perceptions like trust, literacy, and adoption readiness. Descriptive analytics (frequencies, percentages, and charts) are used to visually depict the broad trends. Consent and data screening, respondent demographics, awareness and familiarity, perceived utility, usability and digital trust, behavioral intention to adopt, comparative statistical insights, and overall interpretation are all covered in this chapter.

4.1 Consent and Data Screening

Prior to starting the study, participants had to fill up two consent statements. Although 160 responses were initially gathered, only 113 of them were considered for analysis indicating full informed consent. For ensuring research integrity and safeguarding participant rights, incomplete or partial submissions were eliminated. This screening process improved the

dataset's validity by ensuring that all responses that were analysed adhered to institutional ethical guidelines and accurately represented voluntary participation.

4.2 DESCRIPTIVE ANALYSIS

The google survey forms used for data collection consisted of 25 questions in four sections excluding the consent for participation. The expected sample size was between 100-150 which is sufficient for trend identification and subgroup comparisons (Bryman, 2016a). Even though 160 responses were collected, 113 were retained for data analysis considering the complete consent of participants.

Section 1: Demographics

This section consists of six questions.

- **Age group:**

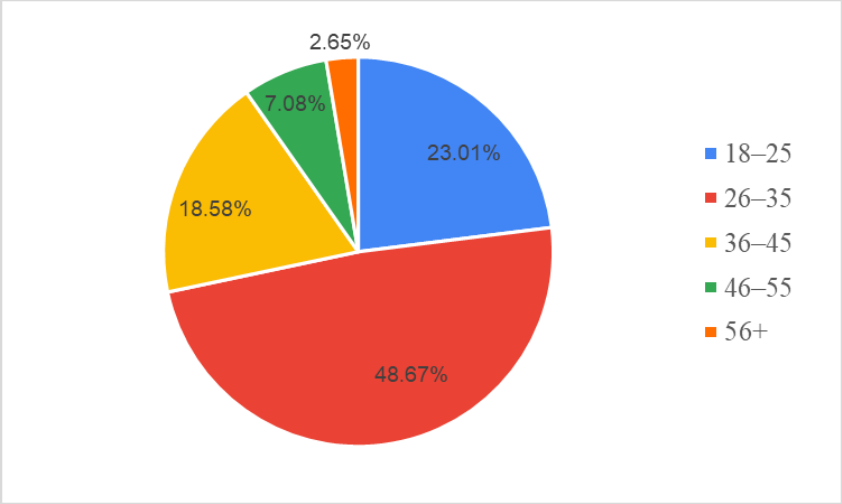

Figure 4. Age group of Respondents

Figure 4. illustrates the percentage of 113 valid respondents of the survey. Majority of the respondents were in age groups 26- 35 followed by 18-25 and 36-45. Remaining minority were aged 46- 55 and above 56 years. It clearly depicts the sample was predominantly young to middle aged adults.

Age Group	Frequency	Frequency Percentage
18 – 25	26	23.01
26 – 35	55	48.67
36 – 45	21	18.58
46 - 55	8	7.08
56 +	3	2.65

Table 2. Age group of Respondents

Table 2. shows that the young and middle-aged respondents have actively participated in the survey like 26- 35 age group consist of 48.67% (55 respondents) followed by 18-25 age group with 23.01% (26 respondents) and 36-45 age group with 18.58% (21 respondents). The remaining population includes 46-55 age group and 56+ age group with 7.08% (8 respondents) and 2.65% (3 respondents).

The predominance of younger respondents shows that they are more digitally confident and adoption-ready, potentially enhancing positive perceptions of SPP. This is consistent to the study by (Yang *et al.*, 2025),where younger adults tend to be more digitally literate and receptive to digital health technologies. While older adults stand to gain the most from SPP and face greater adherence challenges, they are underrepresented because of their lack of confidence in digital tools (Schaefer and Cheung, 2018) which can be seen in the sample. Age distribution is related to the fourth objective which centres on behavioural intention to adopt SPP. The underrepresentation of older age groups—those most likely to benefit—remains a significant limitation given that SPP is intended to support long-term medication management. Although younger cohorts exhibit great promise as early adopters, older adults' viewpoints are still crucial for comprehending the wider applicability of smart pharmaceutical technologies in the Irish healthcare settings.

- **Gender distribution:**

Table 3. shows that out of the 113 repondents, 50.4% and 49.6% of the sample were female and male respectively. This shows an even distribution across the gender.

Gender	Frequency	Frequency Percentage
Female	57	50.4
Male	56	49.6

Table 3. Gender Distribution of Respondents

The dataset's representativeness reduces the possibility of gender bias in the interpretation of the findings. Unlike most of the studies where women has greater involvement in health-seeking behaviors, making up a majority in health-related surveys (Bidmon and Terlutter, 2015). According to earlier research, women tend to be more proactive when it comes to using online health information and show greater intentions to use digital health tools (Neter and Brainin, 2012a; Bidmon and Terlutter, 2015).

As it enables meaningful comparisons between male and female respondents in terms of awareness, trust, and adoption readiness of SPP, this balance is beneficial for analysis. It also offers a solid basis for investigating whether or not these gender-based disparities are apparent in the Irish setting. One limitation is that there were no respondents who did not identify as male or female. In order to ensure more comprehensive insights into the adoption of digital health, future research should be more inclusive in order to better capture the perspectives of non-binary and gender-diverse people.

- **Educational Level**

Education	Frequency
Bachelor's degree	**40**
Diploma	**8**
Graduate's degree	**57**
Primary	**1**
Secondary	**7**

Table 4. Educational level of respondents

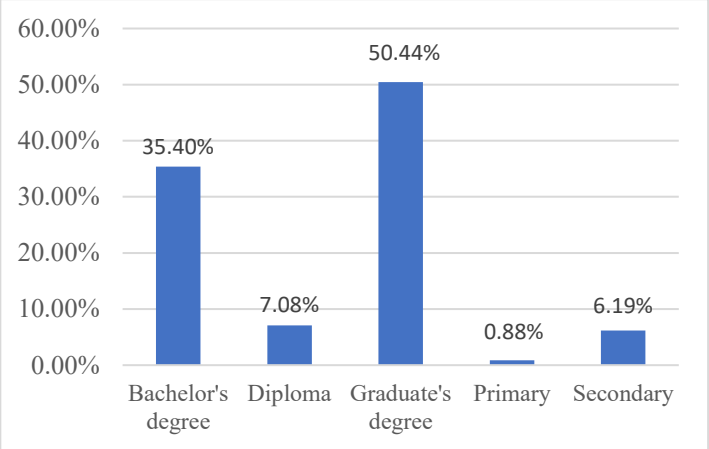

Figure 5. Percentage of Respondents based on educational level

The educational distribution of 113 respondents is summarized and illustrated in table 4. and figure 5. respectively. Majority of participants reported higher education, with 57 respondents (50.4%) holding a graduate degree and 39 (34.5%) a bachelor's degree. The percentages who reported only primary education (2; 1.8%), secondary education (7; 6.2%), and a diploma (8; 7.1%) were lower. This indicates that there is a significant bias in the sample toward those with more formal education. One crucial factor affecting digital readiness is educational qualification. According to earlier studies, people with more education tend to be more digitally

literate, more comfortable using online resources, and more open to implementing digital health technologies (Neter and Brainin, 2012a).

While people with lower education are more likely to have trouble accessing or using digital health resources, recent reviews have confirmed that higher educational status is positively associated with digital health literacy and better use of eHealth tools (Yuen *et al.*, 2024). It has been determined that a major obstacle to the adoption of connected health technologies is a lack of digital literacy, which limits the efficacy of these technologies among populations with lower levels of education (Gualtieri *et al.*, 2018).

The study's sample may represent a population that is already digitally active and prepared for adoption, as indicated by the majority of respondents with university degree. As educated groups are likely to be early adopters, this offers important insights into the potential of smart pharmaceutical packaging. A limitation is highlighted by the underrepresentation of respondents with lower educational backgrounds, which makes it more difficult to evaluate the adoption barriers that people with lower levels of digital literacy face. In order to improve inclusivity and generalizability, future research should try to capture a wider educational spectrum, as SPP is designed to support medication adherence across diverse patient groups, including those who might struggle with usage of technology.

- **Occupation**

Table 5. and figure 6. shows the occupational profile of respondents. Majority of respondents were non healthcare employees (26.55%), followed by healthcare professional (19.47%) and those in other occupation (19.47). Home care assistants (16.8%) and students (11.5%) were among the smaller groups, whereas the least represented groups were caregivers (2.65%), retirees (2.65%), and unemployed individuals (0.88%).

Occupation	Frequency	Frequency Percentage
Caregiver	3	2.65
Healthcare Professional	22	19.47
Home Care Assistant	19	16.81
Non-Healthcare Employee	30	26.55
Other	22	19.47
Retired	3	2.65
Student	13	11.5
Unemployed	1	0.88

Table 5. Occupation of Respondents

A diverse respondent base is indicated by the occupational spread, which balances professional stakeholders (caregivers, home care assistants, and healthcare professionals) with larger public groups (students, non-healthcare employees, and others). Healthcare professionals (19.5%) are likely to facilitate the adoption of SPP in clinical practice. Although issues about workload and system integration may affect acceptance, previous research indicates that clinicians frequently exhibit positive attitudes toward digital health innovations (Ross *et al.*, 2016). By reflecting how the general public views SPP, the inclusion of students (11.5%) and non-healthcare workers (26.5%) expands the scope. Since they directly support medication adherence, caregivers and home care assistants—despite their smaller numbers—represent significant population in the management of chronic diseases.

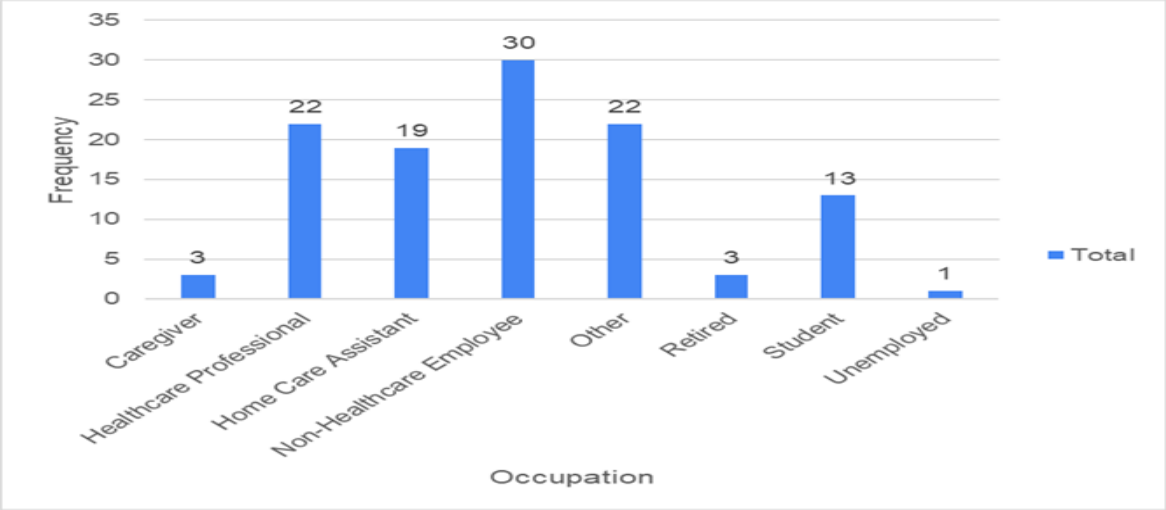

Figure 6. Occupation of Respondents

As patients or non-healthcare workers may have less direct knowledge of new medical technologies than healthcare professionals, who are more exposed to them, occupational diversity is crucial in this context. The clinical benefits and workflow integration of SPP may be used by healthcare professionals to assess its usefulness, whereas usability, privacy, and trust may be more important to non-healthcare participants. Both professional and public viewpoints on SPP are guaranteed to be examined due to this occupational mix. Having these groups represented, even if in smaller numbers, offers insights into real-world adoption readiness, as SPP adoption will rely on not only patients but also caregivers and healthcare personnel who monitor adherence.

- **Medication for Chronic Illness:**

Response	Frequency	Frequency Percentage
Yes	50	44.2
No	61	54
Prefer not to say	2	1.8

Table 6. Medication for Chronic Illness Status of Respondents

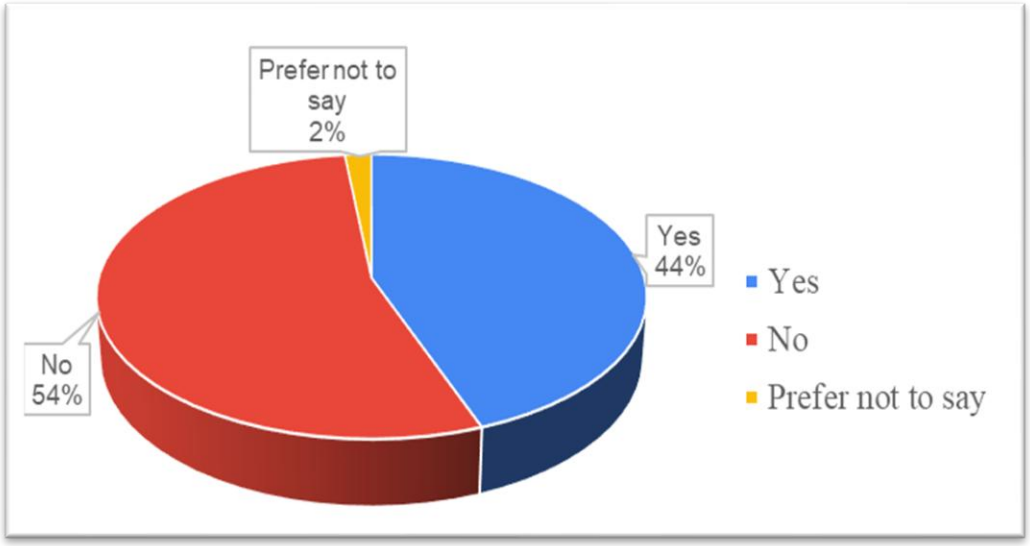

Figure 7. Medication for Chronic Illness Status of Respondents

Respondent's status with chronic illness is shown in Figure 7. and Table 6. of the 113 eligible participants, 54.0% said they had no regular medication for chronic illness, while 44.2% said they had a chronic illness that required regular medication. Just 1.8% of respondents preferred not to disclose it. This equilibrium shows that the survey included people who were directly impacted by difficulties with adherence as well as people who were not chronically ill, enabling a comparison of viewpoints.

For Smart Pharmaceutical Packaging (SPP), the 50 respondents (44.2%) who stated that they needed regular medication are the main target group. Since they can determine whether SPP would meet their daily medication needs, their opinions are closely related to objectives 2 and 4 which is assessing perceived usefulness and ease of use and examining behavioral intention to adopt SPP in chronic disease management). Since broader public perceptions, including those of potential future patients or caregivers, are also crucial for understanding adoption potential, the 61 respondents (54.0%) who did not have a chronic illness offer insightful information about objective 1 which is awareness and familiarity with SPP.

This finding is consistent with earlier studies showing that people with chronic conditions have the most difficulty adhering to their treatment plans, especially when following intricate,

prolonged regimens (Nieuwlaat *et al.*, 2014). To help lower these obstacles and enhance health outcomes, digital interventions like smart packaging have been suggested (Kardas *et al.*, 2013). This study's inclusion of both chronic illness and non-illness groups is consistent with the larger healthcare context, which calls for patient, healthcare professional, and public engagement for the successful adoption of SPP.

- **Digital Literacy**

Response	Frequency	Frequency Percentage
Very Low	**1**	**0.88**
Low	**4**	**3.54**
Moderate	**50**	**44.25**
High	**0**	**0**
Very High	**57**	**50.44**
Prefer not to say	**1**	**0.88**

Table7. Self- reported digital literacy of respondents

The self-assessment of respondent's digital literacy or ease of use of apps and online platforms is displayed in the table 7. Digital literacy was rated as very high by more than half of the participants (50.4%) and moderate by another 44.2%. One respondent (0.9%) opted not to respond, while only a small minority (3.5%) indicated low or very low literacy. A significant finding of this study is that most respondents had moderate to very high levels of digital literacy.

Objective 2 and 3 which is assessing perceived usefulness and ease of use and evaluating digital trust and privacy concerns are closely related to digital readiness because Smart Pharmaceutical Packaging (SPP) incorporates digital features like apps, reminders, and data-sharing platforms. Digitally informed respondents are more likely to understand the value of SPP, use its features with assurance, and evaluate data privacy concerns critically. But the small percentage of participants who are illiterate suggests that there are issues with

inclusivity for objective 4 which is adoption readiness. Digital health tools may be difficult for these people to use, which raises questions about accessibility and the possibility of exclusion.

These findings are consistent with earlier studies emphasizing the part digital literacy plays in influencing the adoption of health technology. Higher eHealth literacy has been shown to increase the likelihood that people will trust and use digital health solutions (Neter and Brainin, 2012b). (Gualtieri *et al.*, 2018) pointed out that a lack of digital skills continues to be a barrier for vulnerable groups, enhancing disparities in access to connected health technologies . Ensuring inclusivity for individuals with lower digital literacy is crucial for equitable adoption of SPP, even though the majority of the sample shows readiness for digital health innovations.

Section 2: Awareness and Perceptions of Smart Pharmaceutical Packaging

- Awareness of smart pharmaceutical packaging (SPP) in Ireland

Responses	Frequency	Frequency %
May be	15	13.27
No	22	19.47
Yes	76	67.26

Table 8. Awareness of SPP among respondents

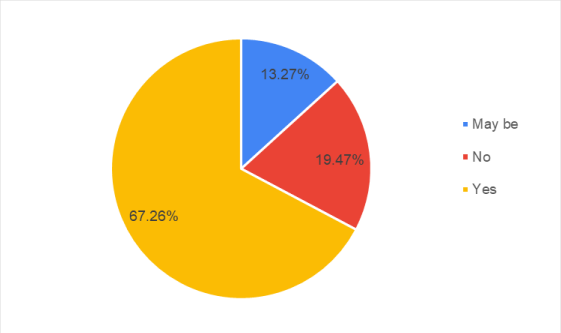

Figure 8. Distribution of Awareness of SPP among respondents

Table 8. and figure 8. shows that out of the 113 respondents, two-thirds (67.26%) were aware of smart pharmaceutical packaging (SPP), whereas 13.3% were unsure and 19.5% had never heard of it. This suggests that uncertainty indicates partial familiarity even though awareness

is relatively high, which directly supports objective 1 which is evaluating public awareness. These findings seem more encouraging when compared to literature that emphasizes the lack of global public awareness of SPP (Pal *et al.*, 2021; Izzah *et al.*, 2022). The existence of responses draws attention to persistent knowledge gaps and emphasizes the necessity of awareness campaigns prior to broader adoption (Quinlan, M. & Priyadarshini, A., 2016).

- Familiarity with Smart Pharmaceutical Packaging (SPP) Concept

Familiarity with SPP	Frequency
Not at all familiar	20
Slightly familiar	32
Moderately familiar	43
Very familiar	18

Table 9. Familiarity of SPP among respondents

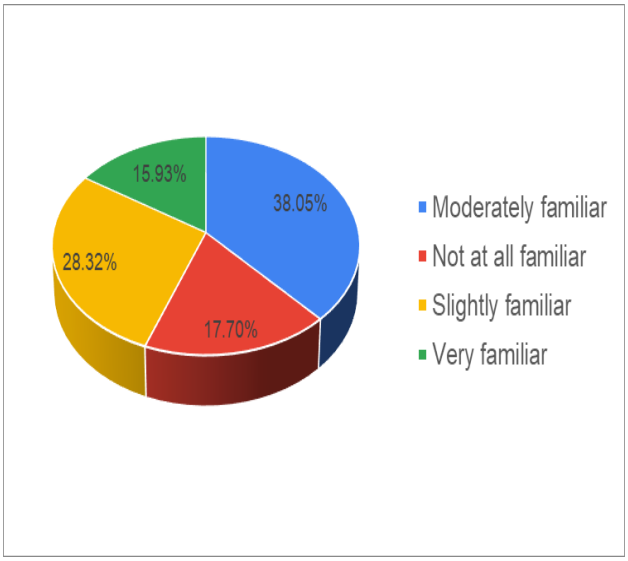

Figure 9. Distribution of Familiarity of SPP

Table 9. and Figure 9. shows that majority of respondents are moderately familiar (43, 38.05%) and slightly familiar (32, 28.32%) with SPP concept. Almost 17.7% are not at familiar (n = 20) and 15.93% are very familiar with SPP concept. This demonstrates that broad awareness does not always equate to a thorough comprehension of the technology, which supports objective 1 which is evaluating awareness and perceptions. The results are consistent with research that shows familiarity with digital health tools frequently lags behind awareness because exposure is typically restricted to theoretical knowledge or pilot programs (Izzah *et al.*, 2022). In order to ensure informed adoption, this gap emphasizes the necessity of improved public communication and demonstration of SPP's functions.

- Perceived usefulness of SPP in improving medication adherence

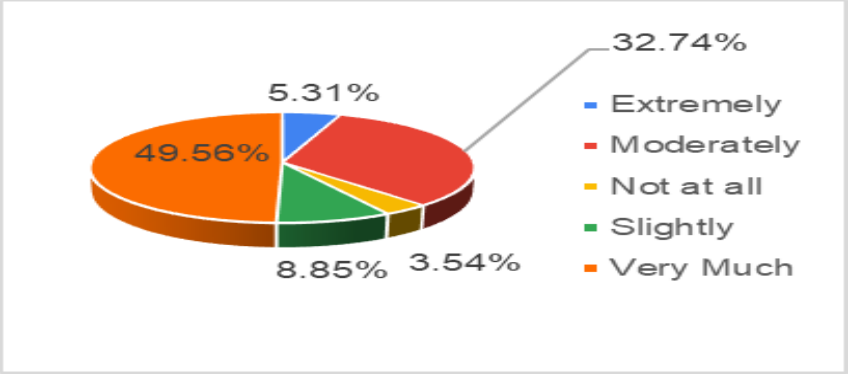

Figure 10. Distribution of perceived usefulness of SPP among respondents

Responses	Frequency
Extremely	**6**
Very Much	**56**
Moderately	**37**
Slightly	**10**
Not at all	**4**

Table 10. Perceived usefulness of SPP among respondents

According to Table 10 and Figure 10, 32.7% of respondents chose "moderate," and nearly half (49.6%) said SPP would significantly increase adherence. 5.3% thought the benefit was extremely high, while only 12.3% were unsure (slightly or not at all). These results directly address objective 2 (perceived usefulness and ease of use), indicating a high level of confidence in SPP's ability to promote adherence. The findings are consistent with research demonstrating that connected packaging and smart reminders enhance adherence in the chronic illness management (Nieuwlaat *et al.*, 2014; Izzah *et al.*, 2022). The minority that expressed skepticism is indicative of persistent obstacles identified in earlier research, such as usability problems or mistrust of digital health tools, which need to be resolved in order to be widely adopted.

- Perceived impact of SPP on chronic disease management

Response	Frequency
Agree	55
Disagree	3
Neutral	34
Strongly agree	18
Strongly disagree	3

Table 11. Perceived impact of SPP on chronic illness management

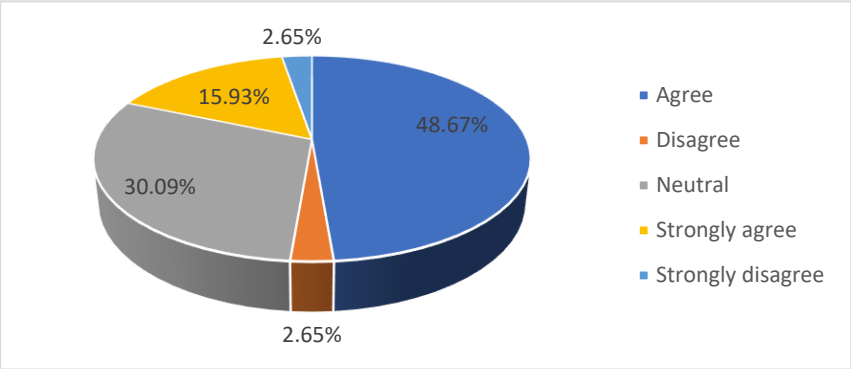

Figure 11. Distribution of perceived impact of SPP in chronic illness management

Table 11. and Figure 11. demonstrates that 64.6% of respondents agreed or strongly agreed that SPP had a positive impact on managing chronic diseases. Just 5.4% disagreed, compared to about 30.1% who were neutral.

By addressing Objective 2 (assessing perceived usefulness) and expanding its perceived benefits beyond adherence, these findings show widespread optimism regarding SPP's role in managing chronic diseases. The sizable neutral group raises the possibility that many respondents might not know enough to assess SPP's impact in its entirety, which is consistent with the previously identified familiarity gaps. This aligns with research that indicates smart packaging holds great promise for managing diseases over the long term, especially when it comes to features like monitoring, reminders, and enhanced communication between patients and providers(Izzah *et al.*, 2022). But in line with earlier research, a minority's skepticism

emphasizes the necessity of more convincing data and practical testing before widespread adoption (Pal *et al.*, 2021).

Section 3: Behavioral Intentions, Medication Adherence and Digital Trust

- Likelihood of use of SPP on recommendation by a healthcare provider:

Response	Frequency
Likely	**56**
Neutral	**22**
Unlikely	**2**
Very Likely	**27**
Very Unlikely	**6**

Table 12. Likelihood of use of SPP among respondents

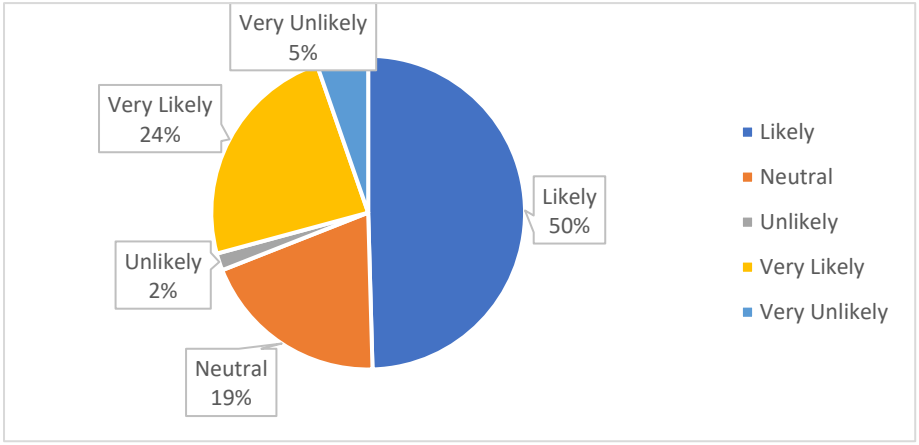

Figure 12. Distribution of likelihood of use of SPP among respondents

Table 12. and Figure 12. demonstrates that the vast majority of participants indicated that they would be open to implementing SPP if a healthcare professional suggested it. 19.5% chose neutral, and nearly three-quarters (73.5%) chose likely or very likely. Reluctance (unlikely or very unlikely) was only 7.1% expressed.

Objective 2, which looks at how functional traits affect adoption intentions, is strongly supported by this finding. Echoing models like UTAUT, the high likelihood of adoption emphasizes the significance of healthcare provider endorsement as a facilitator.

The outcome is consistent with literature, which showed that patient trust and willingness to use digital health technologies are greatly increased by provider recommendations(Venkatesh *et al.*, 2003b; Faisal *et al.*, 2021). It confirms research showing that SPP is more beneficial when incorporated into current care pathways, especially when it comes to managing chronic diseases (Izzah *et al.*, 2022). Uncertainty is indicated by the 19.5% neutral responses, which may be a reflection of knowledge gaps or mistrust of the dependability of technology. The small group of unlikely and very unlikely respondents also reflects the barriers discussed in the literature (Quinlan, M. & Priyadarshini, A., 2016), such as worries about digital readiness, cost, or usability.

- Smart features encouraging SPP adoption :

According to Table 13. and figure 13. , most respondents chose the most desirable features, which included real-time tracking (69.0%), reminders (69.9%), and connectivity with healthcare providers (66.4%). Refill alerts (27.4%) and childproof or tamper-proof packaging (41.6%) were practical but secondary features. Regardless of features, only 3.5% of respondents said they had no interest.

Features of SPP	Frequency	Frequency Percentage
Medication Reminder	79	69.9
Real-time tracking	78	69
Connectivity with healthcare providers	75	66
Childproof or tamper-proof functions	47	41.59
Refill alerts	31	27.43
I wouldn't be interested regardless of features	4	3.54

Table13. Smart features for SPP adoption by respondents

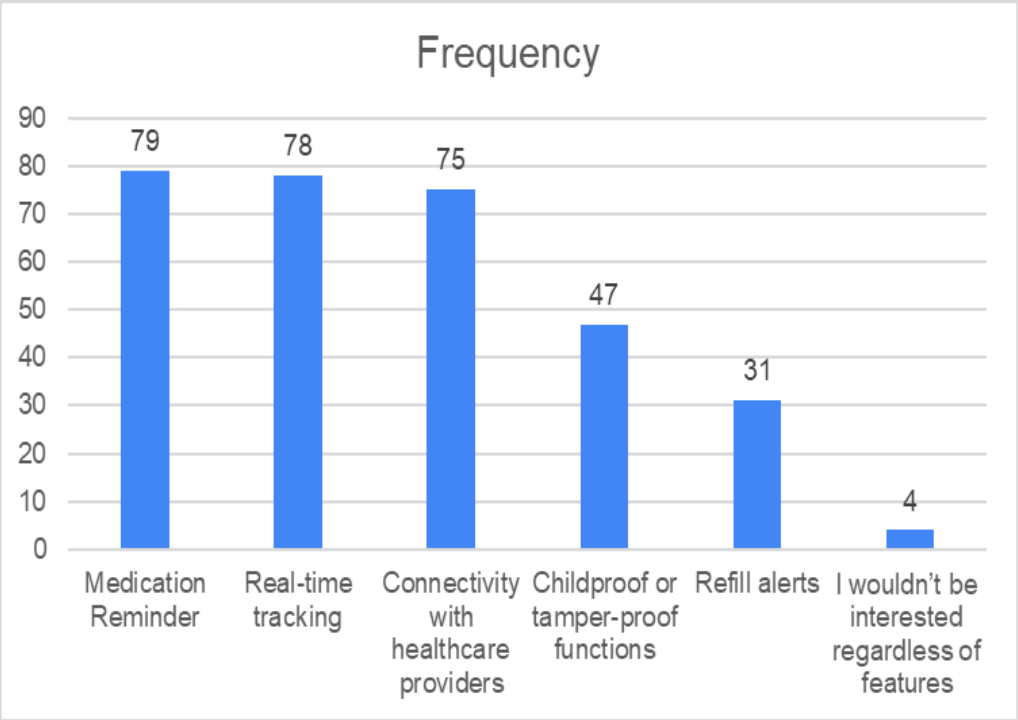

Figure 13. Distribution of smart features for SPP adoption by respondents

Objective 2, which investigates how functional traits affect adoption and adherence, is directly addressed by these results. Features that facilitate daily medication management and integration with healthcare were overwhelmingly prioritized by respondents. This is in line with studies showing that digital monitoring tools and reminders greatly increase adherence in populations with chronic illnesses (Faisal *et al.*, 2021; Izzah *et al.*, 2022).

The literature demonstrating that patient-provider communication improves trust and the uptake of health technologies is further supported by the strong preference for connectivity with healthcare providers (Pal *et al.*, 2021). However, features like refill alerts and tamper-proofing were given less priority, suggesting that users see SPP more as a tool for digital support and adherence than just packaging safety. Adoption resistance is low, as evidenced by the small minority (3.5%) who are uninterested in any features, indicating that SPP uptake has a wide potential if functional benefits are amply demonstrated.

- Likelihood of following medication schedule with SPP reminders:

Response	Frequency
Likely	56
Neutral	22
Unlikely	2
Very Likely	27
Very Unlikely	6

Table 14. Likelihood of following medication schedule with SPP reminders

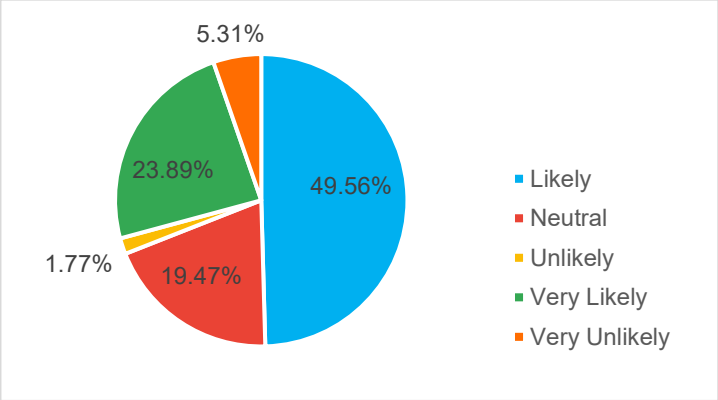

Figure 14. Distribution of likelihood of following medication schedule with SPP reminders

Table 14. and Figure 14. shows that vast majority of respondents said they would heed the reminders that SPP would provide as nearly three-quarters said they were either Very Likely (23.9%) or Likely (49.6%) to stick to the schedule. Just 7.1% (n=8) were unlikely to adhere, whereas a smaller group (19.5%) expressed neutrality, suggesting that attitudes toward reminder-based adherence support are generally positive. This result provides strong support for Objective 2, which examines the effects of smart packaging features on adherence.

The reminder-based support indicates that respondents have a high behavioral acceptance of SPP's primary function, which is to prompt timely medication intake. According to previous research, reminder systems are among the best digital interventions for enhancing adherence

in the management of chronic illnesses (Faisal *et al.*, 2021; Izzah *et al.*, 2022). The minority who was neutral or unlikely to follow reminders might be a reflection of issues that have been identified as obstacles in earlier research, such as reliance on personal routines, digital fatigue, or perceived intrusiveness (Quinlan, M. & Priyadarshini, A., 2016).The data points to the potential for SPP reminders to greatly improve adherence outcomes if properly applied, removing one of the most enduring obstacles in the management of chronic illnesses.

- Confidence in Using Digital Tools and Apps to Manage Health or Medication:

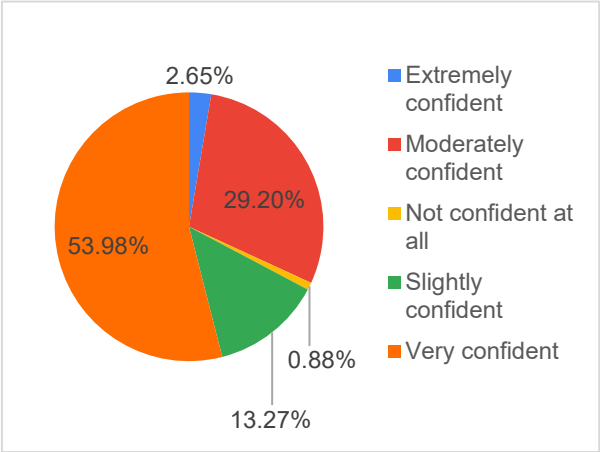

Figure 15. Distribution of confidence in digital tools for medication

Figure15. illustrates majority of respondents expressed strong overall readiness to use digital tools, with 54% being very confident and 29.2% being moderately confident. Merely 14.2% expressed little or no confidence. High confidence levels directly support objective 2 by indicating strong digital readiness. This shows that most participants can use SPP features like tracking and reminders efficiently. But the small group of people who lack confidence is a reflection of the digital divide, which is frequently associated with older adults (Quinlan, M. & Priyadarshini, A., 2016; Schaefer and Cheung, 2018).

- Ease of use of SPP:

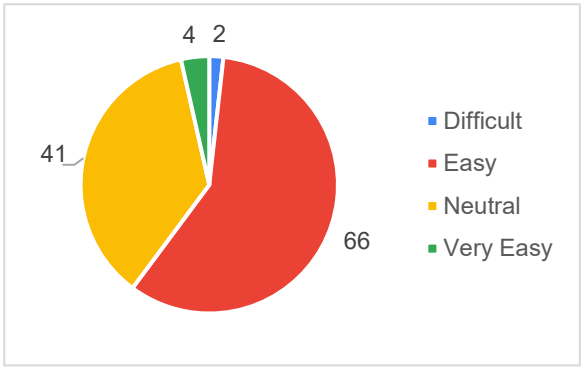

Figure 16. Distribution of Respondents in case of ease of use of SPP

Majority of respondents said they found it easy (58.4%) or very easy (3.5%) to trust SPP reminders, suggesting they were reliable. Just 1.8% found trust difficult, while a 36.3% were neutral, indicating little prior exposure to such technologies. These findings are consistent with Objective 2, demonstrating that adoption depends critically on confidence in the accuracy of the reminders. To increase user confidence in SPP functionality, real-world validation is necessary, as indicated by the neutral responses.

- Confidence in secure storage of personal health data via SPP:

Row Labels	Frequency
Extremely confident	3
Moderately confident	47
Not confident at all	8
Slightly confident	16
Very confident	39

Table 15. Confidence level of respondents in secure personal data storage while using SPP

Majority of respondents (41.6%) and (34.5%) were moderately and very confident, respectively, in the secure storage of health data shared via SPP. Smaller groups reported no confidence (7.1%), very confidence (2.7%), and slight confidence (14.2%). This aligns with

objective 3, which deals with data privacy. Although the general level of trust is positive, the existence of skepticism emphasizes the necessity of strong data protection to boost public trust in the adoption of SPP.

Section 4: Ethical Concerns and Barriers

- Concerns About Data Privacy in Using Digital Health Technologies

Response	Frequency
Extremely concerned	13
Moderately concerned	30
Not concerned at all	4
Slightly concerned	31
Very concerned	35

Table 16. Concerns of respondents about data privacy in using SPP

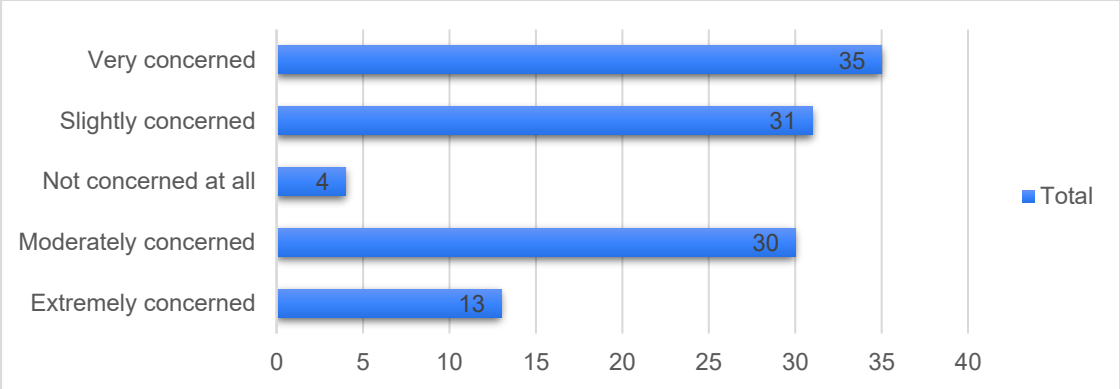

Figure17. Distribution of data privacy concern in using SPP

Table 16. and Figure 17. shows that most respondents expressed moderate to high concern about data privacy, with over two-thirds reporting either moderate, very, or extreme concern (n

= 78). Only a small proportion (**3.5%**) stated that they were not concerned at all. The results show that a key concern in the uptake of digital health technologies is data privacy. Given the high levels of concern, it appears that public acceptance of smart pharmaceutical packaging will depend heavily on trust, safety standards, and open data handling. This aligns with objective 3, which focuses on investigating cybersecurity and privacy in the Irish healthcare context.

- Barriers to Trust and Adoption of Smart Pharmaceutical Packaging

Response	Frequency
Concern about unwanted monitoring or loss of autonomy	63
Concerns about privacy/ security	71
Lack of digital skills	19
Too expensive	54
Not confident in technology	8
Other	9

Table 17. Barriers for SPP adoption and digital trust

Table 17. and Figure 18. shows concerns about privacy and security (62.8%), fear of unwelcome monitoring (55.8%), and expense (47.8%) were the primary obstacles to implementing SPP. Digital skills (16.8%) and technological confidence (7.1%) were less frequently mentioned by respondents.

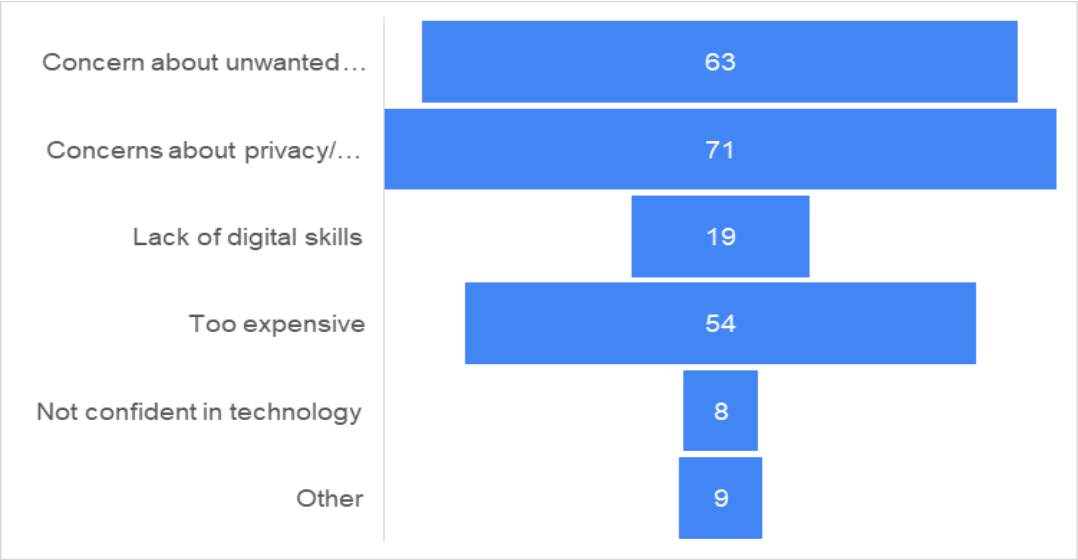

Figure 18. Distribution of barriers for SPP adoption and digital trust

The results indicate that cost, privacy, and autonomy are the main obstacles to the adoption of smart pharmaceutical packaging, with expertise or confidence being less vital. This demonstrates that practical and ethical considerations are more important than technical ones, which directly supports objective 3. SPP needs to be reasonably priced, offer robust data protection, and preserve user autonomy in order to be adopted successfully in Ireland.

- Importance of full control over data shared on SPP adoption

Response	Frequency
Extremely important	27
Moderately important	21
Not important at all	5
Slightly important	6
Very important	54

Table 18. Importance of control over data sharing on SPP usage

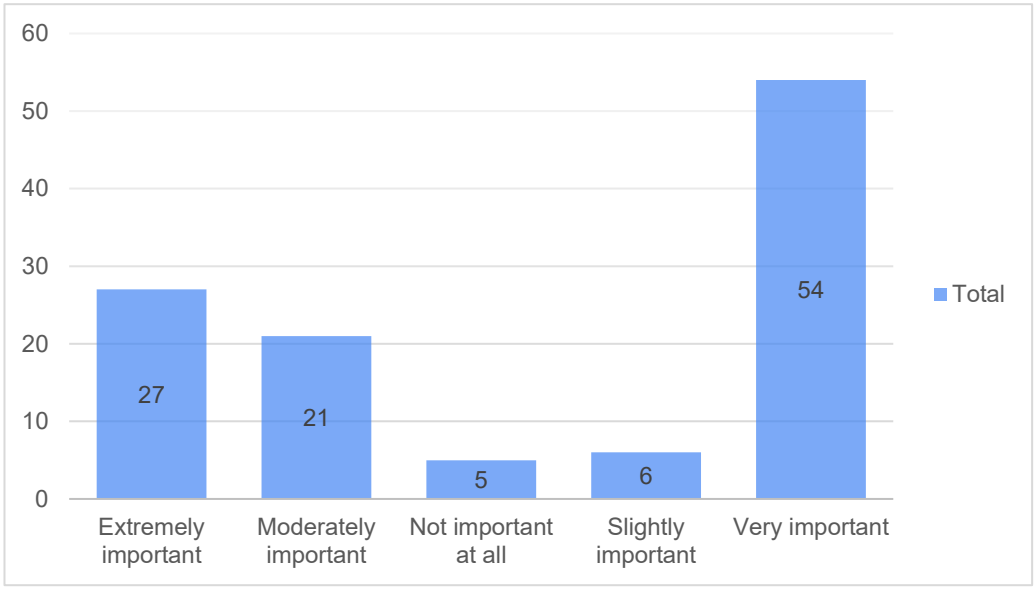

Figure 19. Distribution of importance of control over data sharing on SPP usage

Table 18. and figure 19. shows that 71.7% of respondents said that control over data sharing was very extremely important, indicating that most respondents consider it as essential factor. Although only 9.7% thought it was of little or no importance, a smaller percentage (18.6%) thought it was moderately important.This result directly supports objective 3 by highlighting the importance of user autonomy in fostering public trust in SPP. Respondents obviously want control over who can access and use their health data. The small minority who was less concerned might be people who have less awareness of data risks or more faith in healthcare providers, even though the majority prioritized strict control.

4.3 STATISTICAL ANALYSIS

❖ **Cross-tabulation of Chronic Illness × Adoption Intention**

Chronic Illness Status	Very Likely	Likely	Neutral	Unlikely	Very Unlikely	Row Total
Yes (n=50)	10 (20.0%)	25 (50.0%)	9 (18.0%)	2 (4.0%)	4 (8.0%)	50 (100%)
No (n=61)	16 (26.2%)	30 (49.2%)	13 (21.3%)	0 (0.0%)	2 (3.3%)	61 (100%)
Prefer not to say (n=2)	1 (50.0%)	1 (50.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (100%)
Grand Total (n=113)	27 (23.9%)	56 (49.6%)	22 (19.5%)	2 (1.8%)	6 (5.3%)	113 (100%)

Table 19. Cross-Tabulation of Adoption Intention by Chronic Illness Status

Adoption intention is displayed by chronic illness status in the table. In contrast to 75.4% of respondents without chronic illnesses, 70% (Very Likely + Likely) of respondents with chronic illnesses (n=50) responded that they would be willing to adopt smart pharmaceutical packaging (SPP) if advised to do so by healthcare providers. While resistance (Unlikely + Very Unlikely) was marginally higher among patients with chronic illnesses (12%) than among non-patients (3.3%), neutral responses were comparable (18% vs. 21.3%).This shows that both groups have a generally positive intention to adopt, but it also shows that some people with chronic illnesses are hesitant.

These results are consistent with objective 2, which looked at the relationship between adoption readiness and SPP's functional features. They align with earlier research that highlighted the significant impact of healthcare provider endorsement on the digital health tools adoption(Venkatesh *et al.*, 2003b; Faisal *et al.*, 2021). Greater hesitancy among patients with

chronic illnesses is consistent with findings from Schaefer & Cheung's (2018) research, which found that people with long-term conditions were cautious of new technologies because of usability and trust concerns. Result indicate that provider recommendations are a powerful motivator, however adoption in populations with chronic illnesses still depends on establishing digital trust and removing usability issues.

Cross-tabulation works well for analyzing correlations between two categorical variables, like adoption intention and the presence of a chronic illness, it was chosen. Subgroup differences (such as patients versus non-patients) can be clearly compared using this method, demonstrating how different groups' willingness to adopt SPP differs. Since the study used a non-probability sample, descriptive subgroup comparisons were deemed more appropriate and reliable for achieving the research objectives, and were therefore preferred over more intricate inferential tests.

- **Correlation between Digital Literacy and Adoption Readiness**

The association between respondents' digital literacy and their readiness to embrace smart pharmaceutical packaging (SPP) was investigated using a Pearson correlation analysis. In Microsoft Excel, the =CORREL() function was applied to the paired responses (n = 113), and both variables were coded on a five-point Likert scale.

Correlation coefficient, r = 0.243558

Higher digital literacy was associated with a slightly higher willingness to adopt SPP if advised by healthcare providers, as result showed a weak positive correlation (r = 0.24). Result supports objective 2 by showing that digital competence influences adoption readiness, even though it has weak correlation. Additionally, it is consistent with TAM/UTAUT theory, which holds that behavioral intention is positively influenced by perceived ease of use and technological confidence.

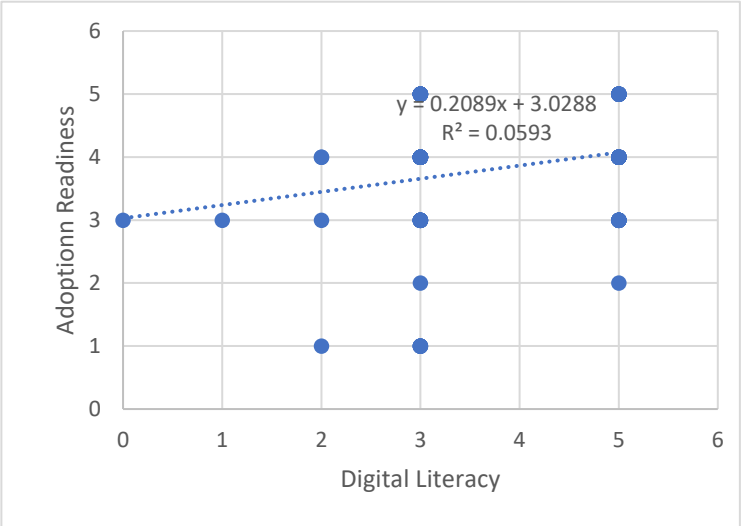

Figure 20. Scatterplot of Digital Literacy and Adoption Readiness

Digital literacy and adoption readiness have a weakly positive correlation, according to the scatterplot. Consistent with the correlation result (r = 0.24), the upward-sloping trendline shows that respondents who scored higher on digital literacy were marginally more likely to report higher adoption readiness. Correlation analysis is suitable for analyzing the direction and strength of the relationship between two Likert-scale variables, like digital literacy and adoption readiness. Correlation offers a simple measure of association that fits with the study's exploratory, non-probability sampling design, in contrast to more intricate inferential techniques.

The scatterplot in Figure 20. illustrates the connection between digital literacy and Smart Pharmaceutical Packaging (SPP) adoption readiness. There is a slight but positive correlation ($r \approx 0.24$, $R2 = 0.0593$), indicating that respondents who are more digitally literate are a little more likely to use SPP. The low R2 suggests that digital literacy only explains a small portion of the variation, underscoring the importance of additional variables like cost, privacy concerns, and healthcare provider endorsement.
This result is consistent with objective 2, which looks at the relationship between behavioral and functional factors and adoption readiness. Additionally, it supports research on the adoption of digital health, which shows that while digital competence helps uptake, it is insufficient on its own (Yuen *et al.*, 2024). According to the results, trust and social influence

are still important factors in adoption, even though digital literacy and ease of use also play a role (Venkatesh *et al.*, 2003b). This is consistent with the TAM and UTAUT models.

4.4 CONCLUSION OF THE FINDINGS

This chapter showed that although there is still a lack of knowledge about Smart Pharmaceutical Packaging (SPP) in Ireland, most respondents acknowledged its benefits for enhancing medication compliance and managing chronic illnesses. The strongest support for adoption readiness came from functional features like real-time tracking and reminders, as well as recommendations from healthcare providers. Concerns about privacy, expense, and disparities in digital literacy, however, still undermine adoption confidence. According to subgroup comparisons, healthcare professionals and respondents who were digitally literate were more prepared for adoption, but some patients with chronic illnesses were more cautious. Digital confidence promotes adoption, but it is not the only factor, according to correlation analysis, which found a weak but positive relationship between digital literacy and adoption intention.

CHAPTER 5

CONCLUSION

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

The purpose of this study was to investigate public perceptions of smart pharmaceutical packaging in Ireland, with an emphasis on awareness, adoption readiness, digital trust, and implications for managing chronic diseases. The data was examined using both descriptive and statistical techniques, and 113 valid responses were analyzed using a quantitative survey method.

The results demonstrated that although SPP awareness is still quite low, the technology is generally regarded as beneficial and has the potential to revolutionize medication management. The most desired features were digital reminders, real-time tracking, and connectivity with healthcare providers, indicating that respondents place a higher priority on useful functionality when thinking about implementing health technologies. The recommendation of healthcare providers emerged as a decisive factor in shaping willingness to adopt SPP, and it is noteworthy that external endorsement had a strong influence on adoption readiness**.**

Adoption was also hindered by concerns, which respondents cited as including usability, possible expenses, and privacy and data security. Many said they needed assurances that their health information would be kept safe and that they would still have control over the sharing of that information. According to subgroup analysis, respondents who were digitally literate and working in healthcare showed higher levels of adoption readiness, whereas those who had chronic illnesses who are most likely to benefit from SPP tended to be more cautious.

Despite the possible advantages for adherence in this group, a cross-tabulation of adoption intention and chronic illness status revealed that patients with chronic conditions were more hesitant than those without chronic illness. Likewise, a weak but positive correlation ($r = 0.24$) was found between digital literacy and adoption readiness. Although this implies that greater digital literacy encourages adoption, it also shows that other elements like affordability, trust, and professional influence are probably more important. Collectively, these results show that although there is cautious optimism regarding SPP in Ireland, addressing ethical, social, and systemic issues as well as highlighting the technological advantages will be necessary for successful adoption.

5.2 Comparison with Literature

First, the study validated the trend in worldwide research that the general public's knowledge of cutting-edge digital health technologies tends to fall short of their potential (Pal *et al.*, 2021; Izzah *et al.*, 2022). Even though a sizable percentage of respondents were aware of SPP, few were familiar with its features and uses. This reaffirms how crucial focused awareness campaigns are to bridge the knowledge gap between innovation and users. Second, the conclusion that SPP is useful for enhancing medication adherence is consistent with earlier research, including Nieuwlaat et al. (2014), which emphasized the significance of interventions to address chronic illness non-adherence. The study's participants acknowledged SPP's capacity to offer structured support and reminders, demonstrating its compatibility with accepted behavioral health theories and practices**.**

Third, adoption readiness was found to be significantly influenced by the endorsement of healthcare providers. This finding aligns with the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Acceptance Model (TAM) (Venkatesh *et al.*, 2003b), which both emphasize how social influence shapes behavioral intention highlighting the importance of trust in healthcare providers in promoting the digital tools adoption.

Fourth, this study revealed significant privacy and data security issues, which shows obstacles found in previous studies on digital health technologies(Schaefer and Cheung, 2018; Gualtieri *et al.*, 2018). Participants conveyed a strong desire for data control and reassurance that their autonomy would not be compromised by digital tools. This implies that ethical guarantees are just as crucial for adoption as technical functionality.

The weak correlation between digital literacy and adoption readiness supports digital competence, but it suggests that digital literacy alone doesn't explain readiness; systemic and trust-related factors are equally significant. Chronic illness patients are more cautious, suggesting cost, perceived complexity, or scepticism may limit adoption.

5.3 Research Conclusions

The Irish public's perception of SPP adoption depends on resolving usability, cost, and trust issues, most respondents think it can enhance medication adherence and chronic disease management. Digital literacy is not the only factor that affects adoption readiness. Although

respondents who expressed greater digital confidence were slightly more likely to adopt SPP, the weak correlation indicates that literacy alone cannot guarantee adoption. Broader systemic components like professional endorsement, affordability, and ethical guarantees must be taken into account.

Adoption is largely driven by healthcare providers supportING the need to integrate these technologies into current care pathways by demonstrating that people are more likely to consider using SPP if a trusted professional recommends it. Even though they are the SPP's intended beneficiaries, patients with chronic illnesses show more reluctance. This paradox implies that it might be more difficult to engage the very group most at risk of non-adherence, and that specific strategies are needed to establish trust, clarify benefits, and remove barriers unique to this group.

5.4 Strategic Conclusions

SPP needs to be incorporated into the delivery of mainstream healthcare in Ireland rather than being offered as a stand-alone innovation in order to be successfully adopted. Continuity of care and increased trust would result from integrating SPP into current prescription, dispensing, and monitoring systems. Establishment of trust needs to be a top concern. It will be crucial to clearly define who controls and has access to health data, adhere to GDPR explicitly, and communicate data protection measures in a transparent manner. Privacy concerns will continue to be a barrier in the absence of such measures.

Digitally literate people are more likely to adopt, but people with less digital literacy or less access to technology run the risk of being left behind. It is crucial to make sure that all patients, particularly those with chronic illnesses and older adults, can access and benefit from SPP as Ireland's healthcare system strives for universality. Affordability needs to be considered to prevent it from becoming an obstacle. To guarantee that access to SPP is fair and not restricted to those who can afford it privately, public funding or integration into national healthcare programs may be necessary.

5.5 Recommendations

- Practical Recommendations: To increase public knowledge of SPP, awareness campaigns should be started, with medical professionals as reliable advocates. To reduce exclusion and foster confidence in technology use, training programs must focus on populations with lower levels of digital literacy, especially older adults. To solve privacy and security issues, strong data protections must be illustrated and explained in detail. Pilot projects should be put into place in Irish healthcare settings to demonstrate the advantages of SPP and boost provider and patient confidence. To avoid financial obstacles to adoption, affordability measures like subsidies or inclusion in public health programs should be implemented.

- Academic Recommendations: Larger, probability-based samples should be used in future research to increase generalizability and representativeness. To evaluate how attitudes and adherence practices change over time with SPP use, longitudinal research is required. It is best to use mixed-methods approaches to integrate qualitative insights about user experience, privacy, and trust with statistical analysis. Comparative research between EU healthcare systems would shed light on the ways in which culture and policy influence adoption. The opinions of healthcare providers ought to be investigated since it has been demonstrated that they have a significant impact on how patients behave.

5.6 Limitations and Contributions

Convenience and snowball sampling, two non-probability sampling techniques, restrict the applicability of results to the larger Irish population. The sample may have been skewed toward younger, technologically skilled people due to the survey's reliance on online distribution, which could have underrepresented older adults who are more likely to have chronic illnesses. Additionally, the cross-sectional design only offers one snapshot in time, making it impossible

to track changing attitudes. Lastly, self-reported metrics are susceptible to bias and might not accurately represent real-world behaviors.

In a field with little research, it offers the first quantitative data on how the Irish public views SPP. It draws attention to adoption's advantages and disadvantages, highlighting the significance of digital literacy, healthcare provider support, and privacy issues. By applying TAM and UTAUT to a new medical technology in an Irish setting, the study also advances theoretical frameworks.

5.7 Suggestions for future research

To increase representativeness, larger-scale surveys employing probability sampling should be taken into account in future research. Studies that follow patients' actual SPP use over time would shed light on how well it serves to improve adherence and health outcomes. The impact of structural and cultural factors on adoption would be emphasized by comparative studies conducted across various healthcare systems. As healthcare providers play a crucial role in influencing patient confidence, more research into their viewpoints is required. Lastly, to ensure that implementation strategies are inclusive and equitable, targeted research on older adults and digitally excluded populations would be crucial.

5.8 Final Reflections

This dissertation's completion has provided new perspectives on how society, healthcare, and technology interact. It has shown me that even though innovations like SPP have a lot of potential advantages, human factors like communication, equity, and trust are ultimately what make them successful. My capacity to perform autonomous quantitative research, interact critically with literature, and decipher intricate results has improved as a result of this project. Additionally, it has brought attention to the significance of ethical issues in digital health, which will guide my future academic and professional endeavors. The process has, above all, taught me the importance of perseverance, flexibility, and critical thinking in carrying out worthwhile research**.**

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APPENDICES

Appendix 1: Privacy and Consent Agreement

You are invited to take part in a research study for my postgraduate dissertation at Griffith College Dublin titled:

"Public Perceptions of Smart Pharmaceutical Packaging in Ireland: Exploring Awareness, Digital Trust, and Adoption Readiness in Chronic Disease Management."

This study aims to explore how people in Ireland understand and respond to smart pharmaceutical packaging—medication packaging with digital features such as reminders, sensors, and connectivity. Your responses will help inform ethical and inclusive digital health policies. It takes roughly ten minutes to finish the survey. Participation is entirely voluntary, and you are free to stop the survey at any moment or skip any questions. All responses are anonymous, and no private data will be gathered.

You confirm that you are at least eighteen years old, presently residing in Ireland, and by continuing you provide your consent to participate in this study.

Your time and insightful comments are greatly appreciated.
For any inquiries,

Researcher: Aabi Anilan

Email: aabi.anilan@student.griffith.ie

Appendix 2: Questionnaire

Consent Confirmation (For GDPR Compliance)

☐ I confirm that I have read and understood the study information and agree to participate voluntarily.

☐ I understand that my participation is anonymous and I can withdraw at any time before submitting the survey.

Section 2: Demographics

- Age Group

☐ 18–25

☐ 26–35

☐ 36–45

☐ 46–55

☐ 56+

☐Prefer not to answer

- Gender

☐ Female

☐ Male

☐ Prefer not to say

☐ Other

- Educational Level

☐ Primary

☐ Secondary

☐ Diploma/Certificate

☐ Bachelor's degree

☐ Graduate degree

- Occupation

☐ Student

☐ Non-Healthcare Employee

☐ Healthcare Professional (e.g., Nurse, Pharmacist)

☐Home Care Assistant

☐ Caregiver

☐ Retired

☐Unemployed

☐Other: _____

- Do you need to take medication on a regular basis for a chronic illness?

☐Yes

☐ No

☐ Prefer not to answer

• How would you describe your level of digital literacy or comfort with using apps and online platforms?

☐ Very Low

☐ Low

☐ Moderate

☐ High

☐ Very High

☐ Prefer not to answer

Section 3: Awareness and Perceptions of Smart Pharmaceutical Packaging

• Have you ever heard of "smart pharmaceutical packaging" (e.g., packaging with sensors, QR codes, or digital reminders)?

☐ Yes

☐ No

☐ Not sure

- How familiar are you with the concept of smart pharmaceutical packaging (e.g., digital reminders, sensors or QR codes)?

☐ Not at all familiar

☐ Slightly familiar

☐ Moderately familiar

☐ Very familiar

☐ Extremely familiar

- To what extent do you believe smart pharmaceutical packaging could help improve medication adherence?

☐ Not at all

☐ Slightly

☐ Moderately

☐ Very much

☐ Extremely

- Do you believe smart packaging can positively impact chronic disease management?

☐ Strongly disagree

☐ Disagree

☐ Neutral

☐ Agree

☐ Strongly agree

Section 4: Behavioral Intentions, Medication Adherence, and Digital Trust

- How likely are you to use smart pharmaceutical packaging if recommended by a healthcare provider?

☐ Very unlikely

☐ Unlikely

☐ Neutral

☐ Likely

☐ Very likely

- Which of the following smart features would encourage you to use smart packaging? (Select all that apply)

☐ Medication reminders

☐ Real-time tracking

☐ Connectivity with healthcare providers

☐ Childproof or tamper-proof functions

☐ Refill alerts

☐ I wouldn't be interested regardless of features

- How confident are you in using digital tools or apps to help manage your health or medication?

☐ Not confident at all

☐ Slightly confident

☐ Moderately confident

☐ Very confident

☐ Extremely confident

- How easy or difficult do you think smart pharmaceutical packaging would be to use?

☐ Very difficult

☐ Difficult

☐ Neutral

☐ Easy

☐ Very easy

- If smart pharmaceutical packaging reminded you to take your medication, how likely are you to follow the schedule consistently?

☐ Very unlikely

☐ Unlikely

☐ Neutral

☐ Likely

☐ Very likely

- How much do you trust smart pharmaceutical packaging to accurately remind you to take your medication?

☐ Not at all

☐ Slightly

☐ Moderately

☐ Very much

☐ Completely

- How confident are you that your personal health data would be securely stored and not misused if shared via smart packaging?

☐ Not confident at all

☐ Slightly confident

☐ Moderately confident

☐ Very confident

☐ Extremely confident

Section 5: Ethical Concerns and Barriers

- How concerned are you about your data privacy when using digital health technologies?

☐ Not concerned at all

☐ Slightly concerned

☐ Moderately concerned

☐ Very concerned

☐ Extremely concerned

- I feel confident using smart packaging without help

☐ Strongly disagree

☐ Disagree

☐ Neutral

☐ Agree

☐ Strongly agree

- Which of the following might make you less likely to trust or use smart pharmaceutical packaging? (Select all that apply)

☐ Concerns about privacy/security

☐ Lack of digital skills

☐ Concern about unwanted monitoring or loss of autonomy

☐ Too expensive

☐ Not confident in technology

☐ Other: _____

- Would you support the use of smart pharmaceutical packaging in Irish healthcare systems?

☐ Strongly oppose

☐ Oppose

☐ Neutral

☐ Support

☐ Strongly support

- How important is it for you to have full control over how your medication data is shared?

☐ Not important at all

☐ Slightly important

☐ Moderately important

☐ Very important

☐ Extremely important

- Would you support the integration of smart pharmaceutical packaging in Ireland's healthcare system, if concerns around privacy, cost, and usability were addressed?

☐ Strongly oppose

☐ Oppose

☐ Neutral

☐ Support

☐ Strongly support

Appendix 3: Participation Information Letter

GRIFFITH COLLEGE

Participant Information Letter

Public Perceptions of Smart Pharmaceutical Packaging in Ireland: Exploring Digital Trust, Medication Adherence, and Adoption Readiness in Chronic Disease Management

I would like to invite you to take part in a research study. Before you decide you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or if you would like more information. Take time to decide whether or not to take part.

WHO I AM AND WHAT THIS STUDY IS ABOUT

My name is Aabi Anilan, and I am a postgraduate student at Griffith College/Innopharma Education. This study is part of my Master's dissertation for the MSc in Digital Transformation. The purpose of this study is to investigate the perceptions of the Irish public regarding smart pharmaceutical packaging (SPP), including those who have chronic illnesses, caregivers, and medical professionals. In order to enhance medication adherence and health outcomes, these packaging systems incorporate digital features like sensors, mobile connectivity, and reminders.

WHAT WOULD TAKING PART INVOLVE?

Participation requires completing a 10- to 15-minute, one-time, anonymous online survey. Your knowledge of smart packaging, ease with digital tools, confidence in data handling, and readiness to use such technology will all be tested. You can stop the survey at any moment or skip any questions. There is no audio or video recording or interview

WHY HAVE YOU BEEN INVITED TO TAKE PART?

Because you are an adult (18+) residing in Ireland, you have been invited. You may be a caregiver, a healthcare professional involved in patient care, or someone with a chronic illness. Your viewpoint is helpful in figuring out how various groups may react to this technology.

DO YOU HAVE TO TAKE PART?

It is entirely voluntary to participate. Before completing the survey, you have the option to withdraw at any moment, refuse to participate, or choose not to respond to any questions. If you decide not to participate, there are no repercussions. Before submitting the survey, please email me at aabi.anilan@student.griffith.ie if you would like to remove your data. Responses are anonymous and untraceable once they are submitted.

WHAT ARE THE POSSIBLE RISKS AND BENEFITS OF TAKING PART?

This study is low risk. Questions about health, digital privacy, or medication use may come up, which could make some people feel a little uncomfortable. You can, however, skip any question at any moment. This research will help us understand how to design and implement digital health tools in a way that is inclusive, ethical, and patient-centered.