MSc Healthcare and Design Project

Can design thinking help to understand patients with medication compliance issues and generate insights to improve healthcare outcomes?

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Abstract

Taking medications as prescribed is vital for managing chronic conditions, treating temporary illnesses and improving overall health outcomes. Unfortunately, a significant proportion of patients fail to take their medications according to their prescribed regimens.

This study aims to adopt a design thinking approach to understand patients' medication compliance issues and generate actionable insights to improve health outcomes.

Through a combination of primary and secondary research, we sought to understand the shared behaviours and challenges that patients with poor medication compliance face. By acknowledging our target audience and their needs, we uncovered recurrent themes that had to be addressed to develop an effective solution.

A proposed design concept was selected and developed into a functioning prototype following a brainstorming and ideation process. The development process was part of an iterative cycle with continuous usability and desirability testing alongside end-user participation through co-design workshops and interviews.

This research provides insight into the behaviours and patterns that patients with medication non-compliance exhibit. The application of a design thinking approach demonstrates its effectiveness in delivering a user-centred product. The author hopes that this study's insights and results will prompt future research and development in this area and promote the use of design thinking in more healthcare challenges in the future.

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List of Abbreviations

AF	Atrial Fibrillation
AI	Artificial Intelligence
BD	Twice Daily
CCGs	Clinical Commissioning Groups
COPD	Chronic Obstructive Pulmonary Disease
COVID-19	Coronavirus disease, SARS-CoV-2 virus
GP	General Practitioner
MCCA	Multi-Compartment Compliance Aid
MDT	Multi-Disciplinary Team
NHS	National Health Service
NICE	The National Institute for Health and Care Excellence
OD	Once Daily
RPS	Royal Pharmaceutical Society
SPS	Specialist Pharmacy Service
TDS	Thrice Daily
UK	United Kingdom
UX	User Experience

1 Introduction

1.1 Background

Taking medications as prescribed is vital for managing chronic conditions, treating temporary illnesses and improving overall health outcomes.

Community pharmacies dispense over 1.1 billion prescription items in the United Kingdom (UK) every year (1). These items are provided for the treatment of minor ailments (indigestion, travel sickness), long-term conditions (insulin for diabetes) and as preventative medication (anticoagulation to prevent strokes), and they result in over £16 billion spent annually on medications (2).

1.2 Medication Non-Adherence

Unfortunately, a significant proportion of patients fail to take their medications as prescribed.

A study by Omnicell (3) of 2000 adults in the UK found that over 20 per cent were missing at least one round of medication every day (Figure 1). Research conducted by Age UK (4) suggests that this number increases to up to 50 per cent amongst the elderly population (aged over 60), as shown in Figure 2.

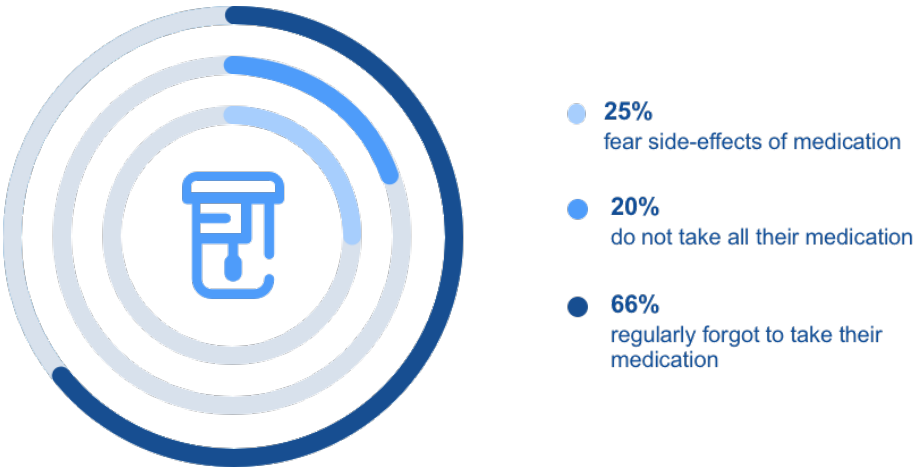

Figure 1. *Medication non-adherence Omnicell survey results (3)*

A further 20 per cent of patients stop taking their prescribed medication when they feel they no longer need it (4). In addition, patients taking medication for mental health issues, such as depression, were twice as likely to stop taking their medication than those with heart disease or diabetes.

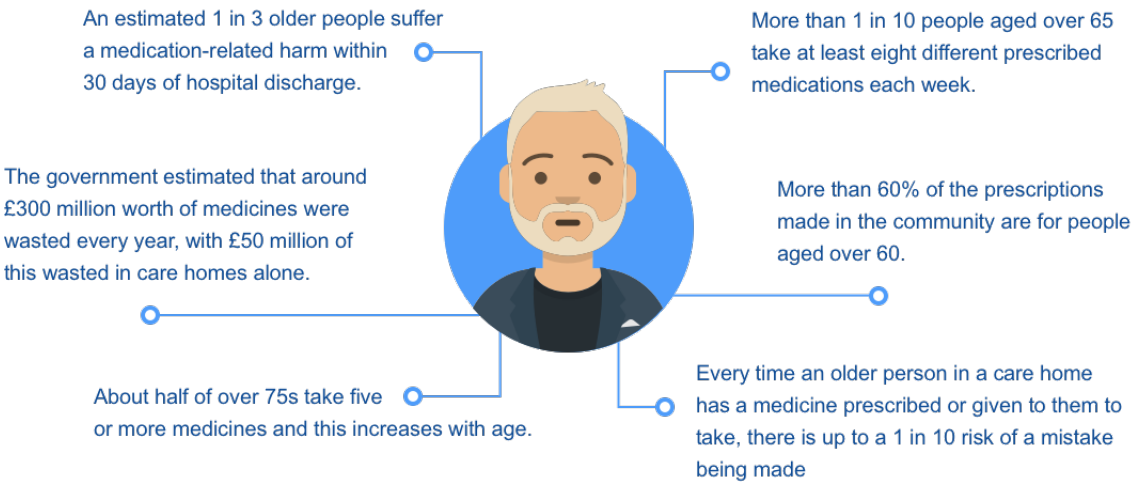

Figure 2. *Elderly medication non-adherence according to studies by Age UK (4)*

Individuals on polypharmacy are particularly affected by this issue, where they find it increasingly difficult to remember multiple daily doses of medications. In England, nearly one in four people aged over 85 years take eight different prescribed medications each week (4).

These unused medications are often disposed of, with only six per cent of individuals alerting their clinicians that they have discontinued their medication regimens (3). As a result, these medications continue to be dispensed regularly and are ultimately wasted.

Consequently, medication wastage alone costs the NHS £300 million every year (5). Medication non-adherence generates waste and leads to worsening health outcomes, particularly in individuals with chronic health conditions (Figure 3). These interrupted treatment regimens often lead to higher hospitalisation rates and mortality, resulting in further personal, health, and social costs (6).

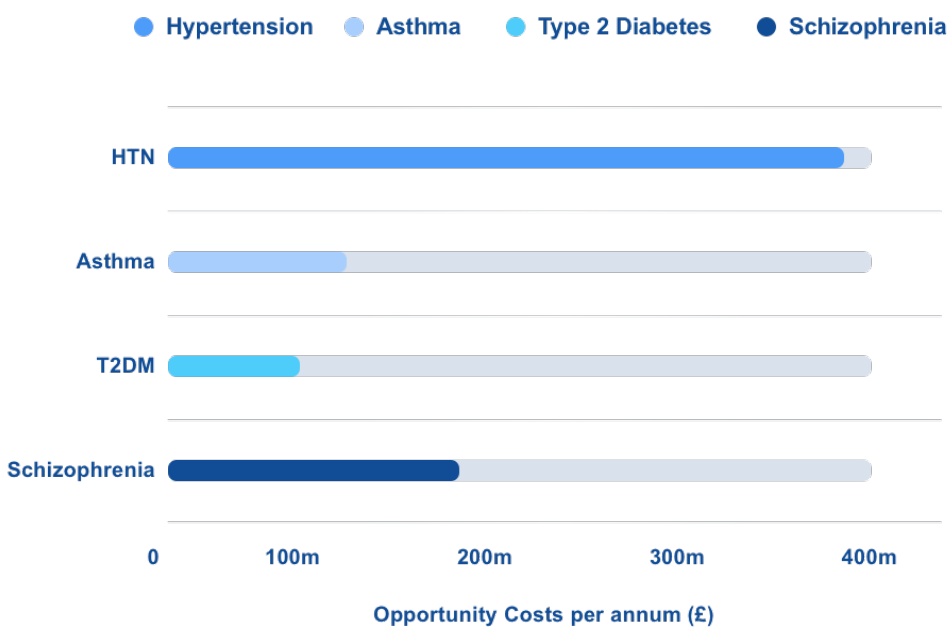

Figure 3. *Opportunity costs lost due to interrupted treatment regimens (6).*

An example of this issue would be the use of bisphosphonates to manage osteoporosis, a condition that weakens bones and increases susceptibility to fractures. These drugs cost only £0.26 per tablet and have proved effective when used correctly (7). However, non-adherence increases the risk of hip fractures, costing the NHS approximately £20,000 to treat (3).

As our population ages and more people have long-term health conditions, these issues are likely to become more prevalent in the future. Therefore, it is vital to study medical compliance behaviours to understand better how we could improve medication compliance in the community.

1.3 Improving Medication Compliance

The Specialist Pharmacy Service (SPS) has identified several ways to support patients in taking their medications (8). Some examples include regular medication reviews, simplifying medication regimens, avoiding unnecessary polypharmacy, and using multi-compartment compliance aids (MCCAs) to support patients' self-administration of medicines (Figure 4).

Figure 4. *Methods to support patient medication use (9)*

However, there is limited research evaluating the effectiveness of such methods, particularly regarding MCCAs. Furthermore, these solutions may not work across different members of the population. Consequently, published evidence has suggested that patients with medication compliance issues should undergo an assessment to identify which aids or supporting strategies are best suited for them (10).

The National Institute for Health and Care Excellence (NICE) and the Royal Pharmaceutical Society (RPS) have also stressed the importance of designing a tool to identify, assess, and resolve medication compliance issues (8,11,12). This tool would ideally aid in implementing and refining solutions that promote medication compliance and support patients throughout the process. Because no such tool currently exists, we

would design a model to evaluate existing products and proposed interventions during our research.

1.4 Design Thinking in Healthcare

Within healthcare, policies and treatments are often guided by patient-centred care. IDEO, a global design and innovation company, described design thinking as a process that prioritises user-centred research and builds upon a deep, empathetic connection with participants to understand their needs, challenges, and desires (13,14). It may, therefore, be appropriate to utilise these techniques to understand patients and their needs better.

Design thinking describes an iterative cycle of three core phases: inspiration, ideation, and implementation (Figure 5). Inspiration typically begins with identifying the design challenge utilising literature reviews, user observations and user feedback. Ideation challenges the creative boundaries in the generation of ideas and concepts in solving the problem. Implementation brings together the knowledge and understanding of the design challenge to refine generated ideas into potential solutions.

This proposed process can bring together insights from patient interviews, direct observation in clinical settings, and feedback from the multi-disciplinary teams (MDT) in order to enhance patient experiences and improve clinical outcomes.

Divergent and convergent thinking is promoted throughout the iterative design thinking cycle (Figure 6). Divergent thinking encourages researchers to open their minds to new possibilities, such as utilising brainstorming tools. Convergent thinking focuses on the

most promising ideas to evaluate and perfect solutions' desirability, viability and feasibility (Figure 7).

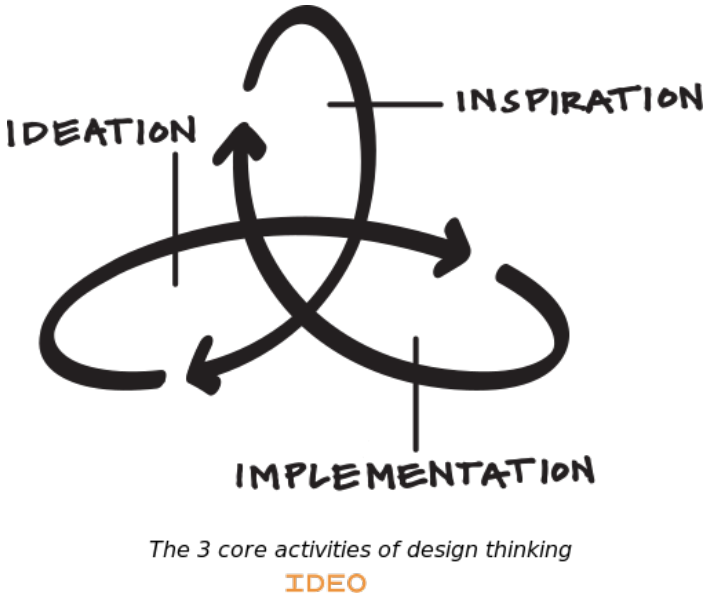

Figure 5. *IDEO Design Thinking: ideation, inspiration, implementation* (13)

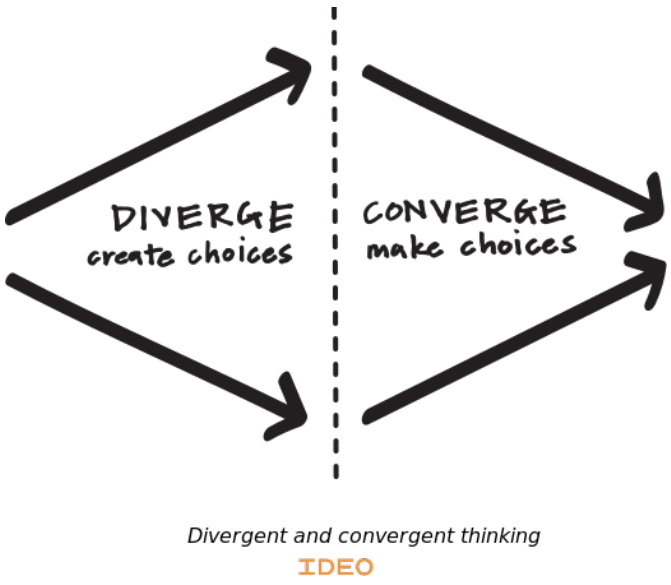

Figure 6. *IDEO Design Thinking: divergent and convergent thinking* (13)

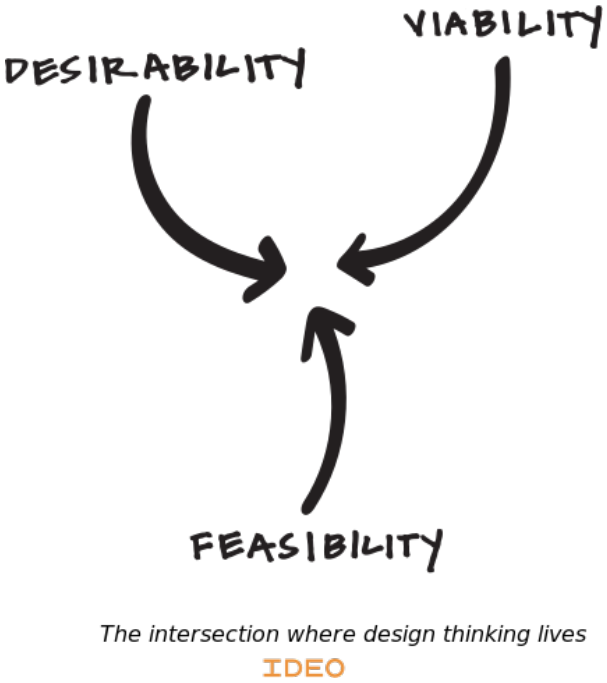

Figure 7. *IDEO Design Thinking: desirability, viability, feasibility* (13)

Linear analytical methods, traditionally used in healthcare, are appropriate for studies where a problem is clearly defined and few individuals are involved in the problem or the solution (15). One example of this context is clinical trials where researchers investigate the efficacy of a new medical drug.

In contrast, design thinking relies on qualitative research methods, such as user observation and interviews, when identifying a design challenge and excels in studies where a deep understanding of the actual users is essential. This methodology helps identify difficulties such as patient frustrations due to a lack of understanding of their health, which may not have been apparent in traditional research (Figure 8).

A human-centred approach should therefore be vital in understanding and implementing changes in a healthcare environment. Applying a design thinking approach in healthcare research can gain new insights into how individuals and their

communities experience healthcare problems and understand the unfulfilled user needs to frame our design challenge (16).

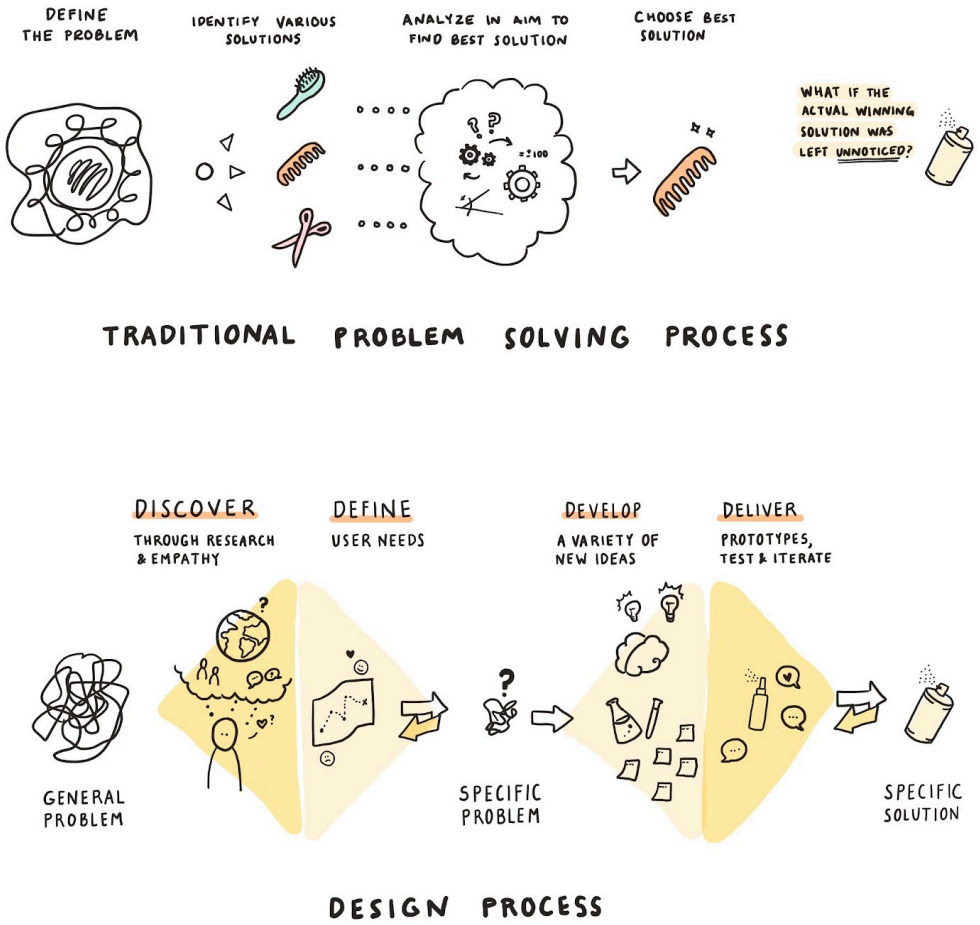

Figure 8. *Differences between linear research and design thinking* (17)

1.5 Study Objectives

This dissertation aims to gain insight into medication compliance issues amongst patients and explore potential solutions to this problem. It highlights the challenges patients face, the impact of existing solutions, and the integration of design thinking in developing an innovative solution to tackle these issues. The research question and specific research objectives are presented below.

Research Question

Can design thinking help understand patients with medication compliance issues and generate insights to improve healthcare outcomes?

Specific Objectives

- To understand medication compliance and methods to support patients with adherence to medication regimens through a literature review
- To identify shared behaviours and challenges in patients with medication compliance issues through patient interviews and surveys
- To develop a model for evaluating medication compliance in new and existing innovations
- To design and test a solution that improves medication compliance in patients in the UK, including insights into industry attractiveness and sustainability of the product

2 Methods & Methodology

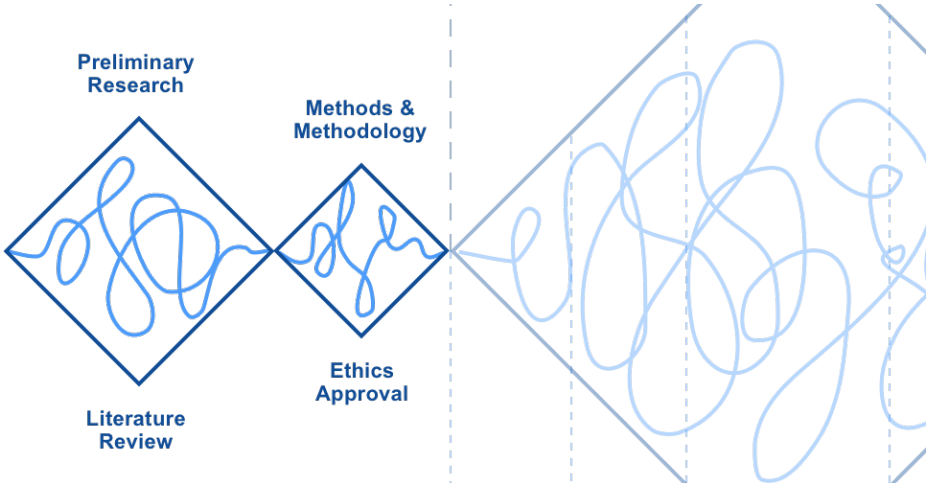

Figure 9. *Methods & Methodology Process*

2.1 Structuring the Project

This dissertation aims to utilise a design thinking approach to identify challenges patients face with medication compliance issues and design an intervention to improve adherence to medication regimens.

We adopted the Double Diamond creative process in our methodology to encourage divergent and convergent thinking throughout our study (Figure 10). The Design Council (18) breaks the design process into four stages:

- Discover. Gaining insights through primary and secondary research to understand the issues people are facing (Divergent)
- Define. Consolidating the insights gained in the previous phase to define the design challenge (Convergent)

- Develop. Brainstorming and generating ideas to innovative solutions to a clearly defined problem, seeking inspiration from various sources (Divergent)
- Deliver. Building, testing and iterating the most promising ideas to deliver a final solution (Convergent)

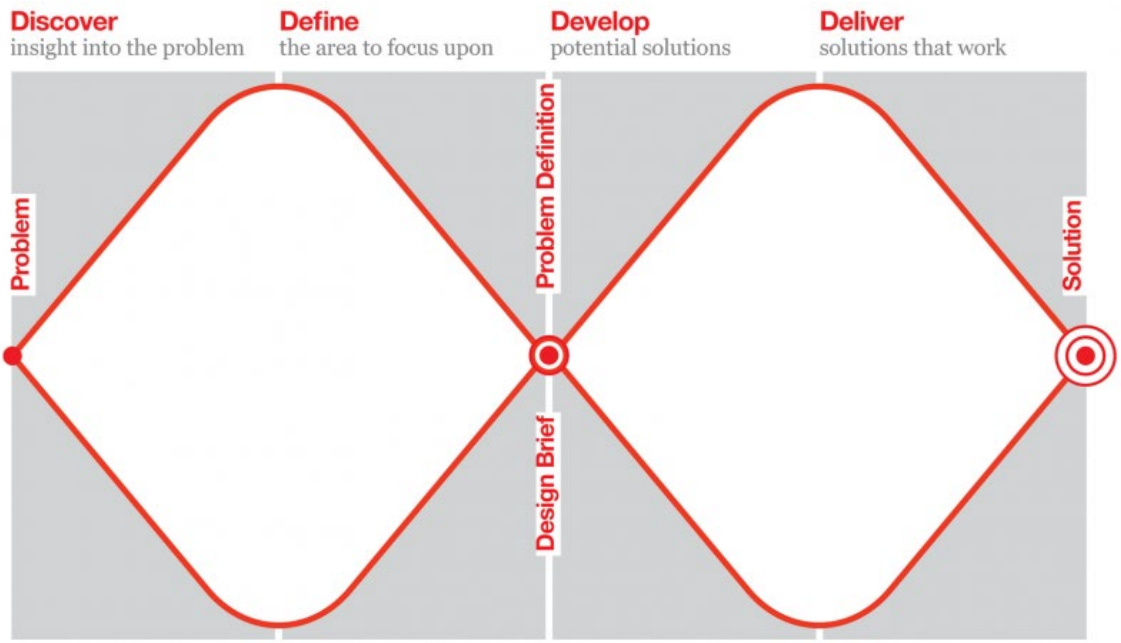

Figure 10. *Original Double Diamond Model* (18)

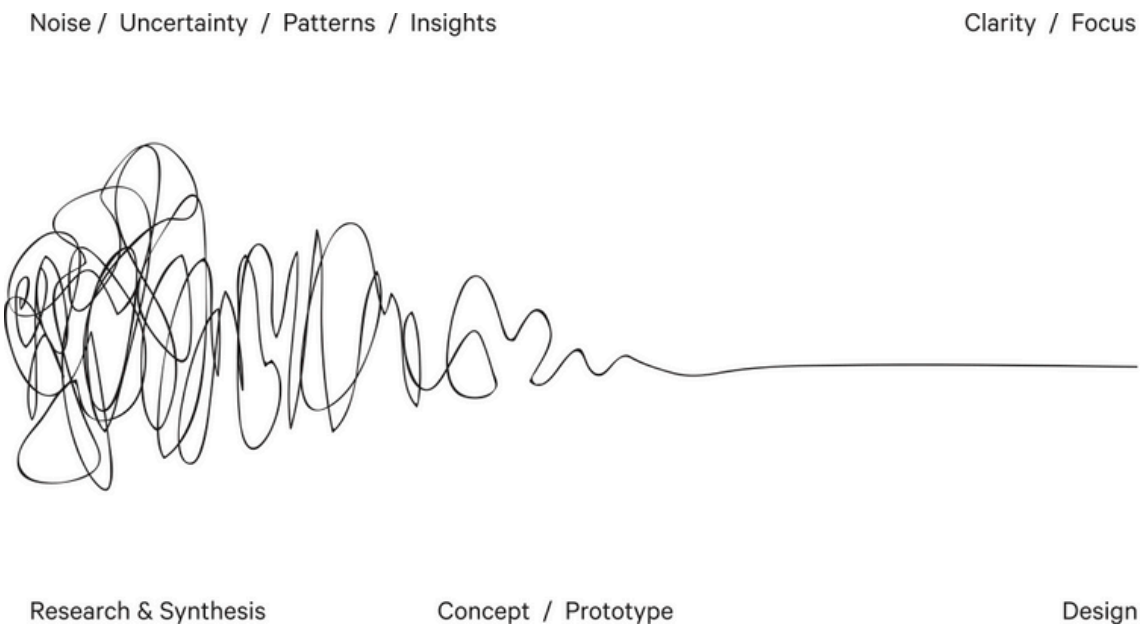

Figure 11. *Design Squiggle* (19)

The Design Squiggle (Figure 11), illustrated initially by Damien Newman (19), describes the product journey from 'uncovering insights' and 'generating creative concepts' to reaching a point of clarity in a single, well-designed solution.

Consequently, the author designed an Adapted Double Diamond framework, incorporating the Design Squiggle, to guide the reader through this dissertation (Figure 12).

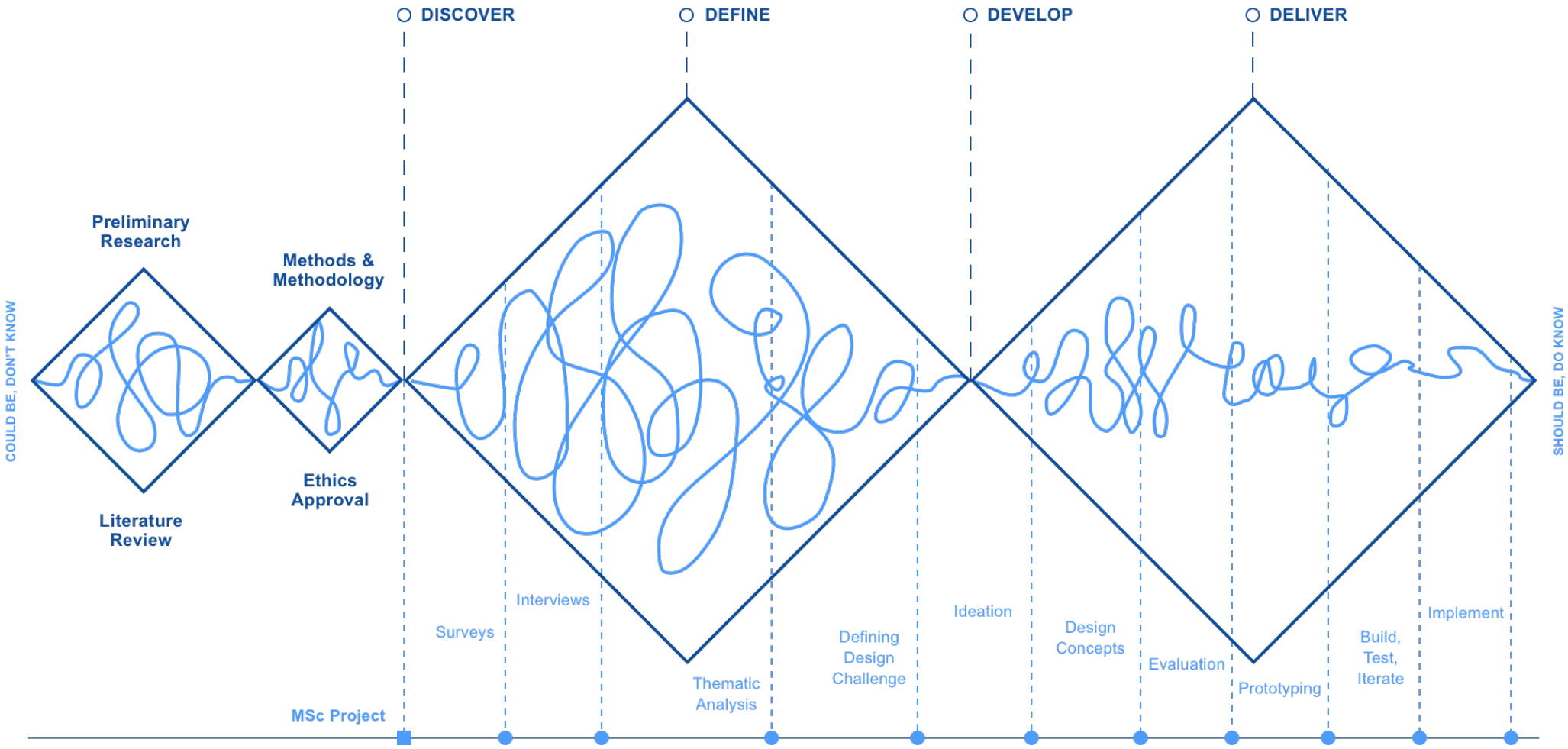

Figure 12. *Adapted Design Squiggle and Double Diamond Process*

2.2 Research Approach

This study follows a human-centred design approach utilising the Adapted Double Diamond framework and incorporates mixed research methods to gather qualitative and quantitative data (Figure 13).

Figure 13. *Research Approach*

2.2.1 Discover

The purpose of this stage is to gain insights into the issues patients with poor medication compliance were facing through primary and secondary research.

Objective

To identify shared behaviours and challenges in patients with medication compliance issues.

Primary Research

The primary research was conducted in two parts:

Part 1: Survey

Individuals living in the UK were invited to participate in an online Typeform (20) survey shared using social media platforms. The target audience for this survey were patients with chronic medical conditions, such as diabetes and heart disease, who were administering their medication.

Questions were formulated based on our research objective (Figure 14). The survey adopted design techniques recommended by Brace (21) to minimise bias and avoid ambiguity in the questions and responses. An example of this approach is the randomised rotation of questions to mitigate any potential ordering bias. A copy of the final survey can be found in Appendix **A**.

Survey responses consisted of a mixture of qualitative and quantitative data, which were grouped under recurring themes.

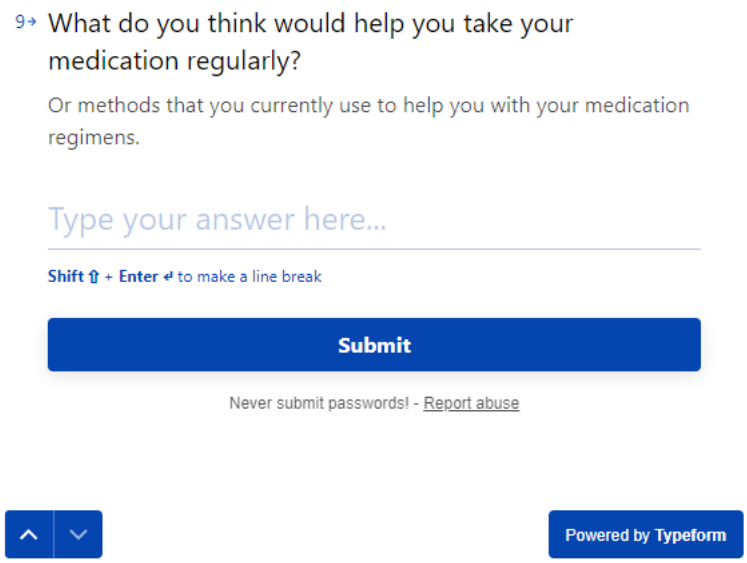

Figure 14. *Typeform User Survey Design* (20)

Part 2: User Interviews

Ten participants were invited for a series of user interviews to explore their experiences with the self-administration of medication. These interviews were conducted as part of the MSc Healthcare & Design course during the Helix Design Dash, a collaborative one-week sprint challenge of identifying opportunities and prototyping innovations in the healthcare space.

Due to the current COVID-19 restrictions in the UK, interviews were conducted over Zoom (22) and Google Meet (23). The interviews followed a semi-structured style (24), combining pre-defined questions seen in structured interviews with an open-ended exploration of the research objective (Figure 15). The final list of questions can be found in Appendix **B**.

After the interviews were conducted, notes and recordings from each session were collated and analysed. Common themes identified from the responses to open-ended questions were grouped and mapped into user personas to represent the users' needs, experiences, and behaviours.

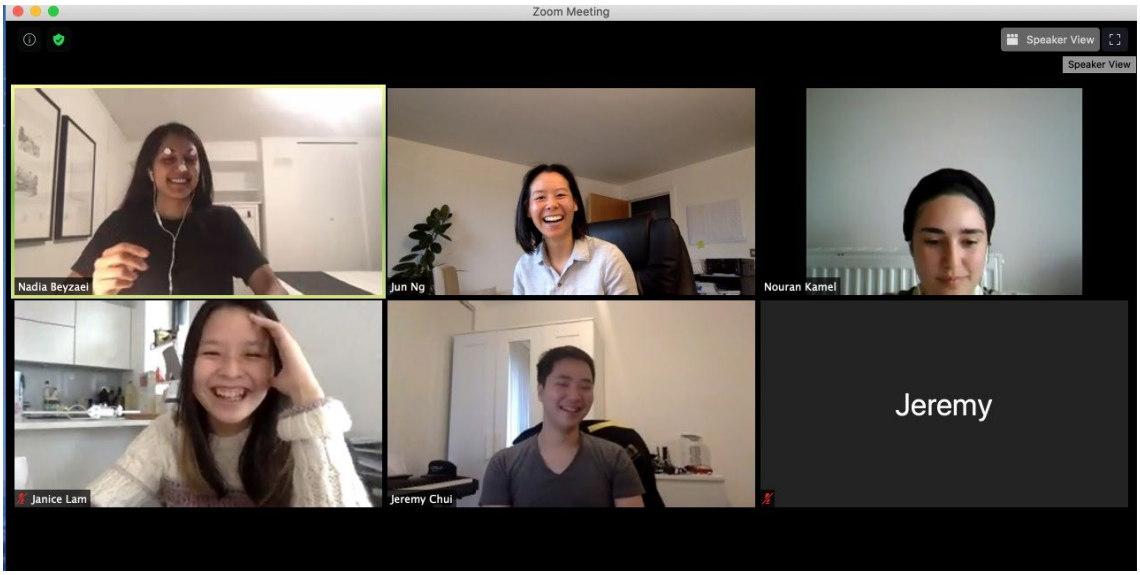

Figure 15. *Design Process: User Interviews over Zoom and Google Meet*

Secondary Research (Literature Review)

Objective

To understand medication compliance and methods to support patients with adherence to medication regimens.

Literature Review

A review of the existing literature was conducted to consolidate what was already known about medication compliance and enable the author to identify knowledge gaps that our primary research could complement.

The author used the OVID (25) search engine to search the MEDLINE and Embase research databases for relevant papers; setting the following limits during our literature review:

- Search Terms: ((medication* or medicine*) adj (compliance* or adherence*)).mp.
- Inclusion Criteria: Within the last ten years, English language, UK based, Peer-reviewed studies.
- Exclusion Criteria: More than ten years, Non-English language, Non-UK based, Non-peer reviewed studies, Duplicates.

The OVID search resulted in **549** papers that met our initial criteria. A further limit was established to remove unavailable journals across multiple platforms. A manual evaluation of the articles for eligibility and relevance to our study was conducted. Subsequently, a total of **13** papers were identified and cited in our final literature review.

These papers were thematically analysed and systematically evaluated for recurring themes, with an additional **two** records identified through further searches to supplement knowledge and insight for our study (Figure 16).

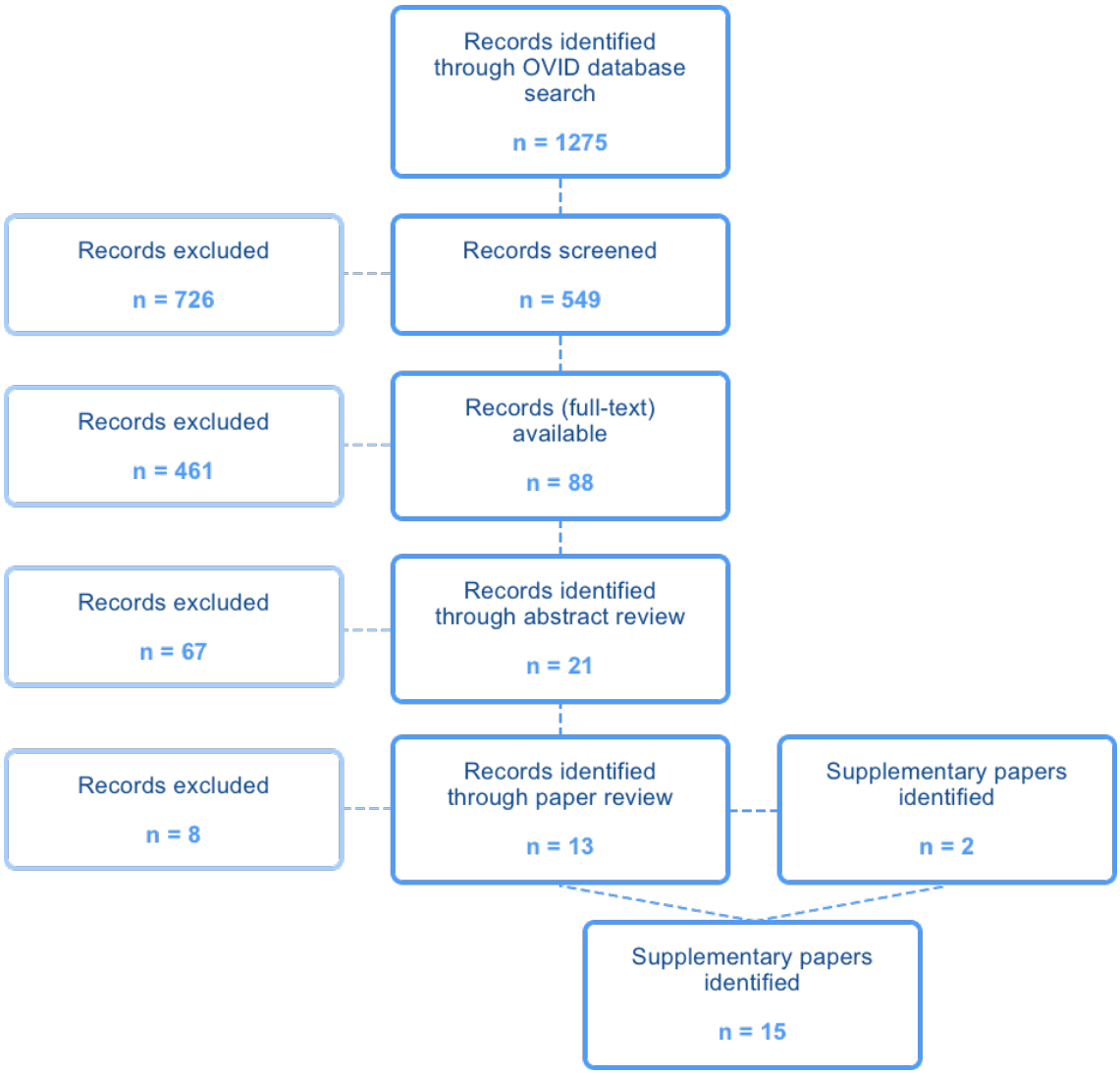

Figure 16. *PRISMA Diagram demonstrating Literature Review*

2.2.2 Define

The purpose of this stage is to consolidate the insights, themes, and opportunities identified in the previous step to focus on a clearly defined problem.

The author validated the need to improve medication compliance in order to improve health outcomes in the previous stage through primary and secondary research. A clearly defined design challenge is, therefore, necessary to guide our research.

Michie et al. (26) proposed that people required capability (C), opportunity (O), and motivation (M) to perform a targeted behaviour (B). Capability is defined as the attribute a person has that makes the behaviour physically and psychologically possible. Opportunity is the physical or social attribute of the surrounding system that makes the behaviour possible. Finally, motivation is the mental process that directs behaviour. This insight led to the creation of the COM-B model to guide designers towards developing effective interventions (Figure 17).

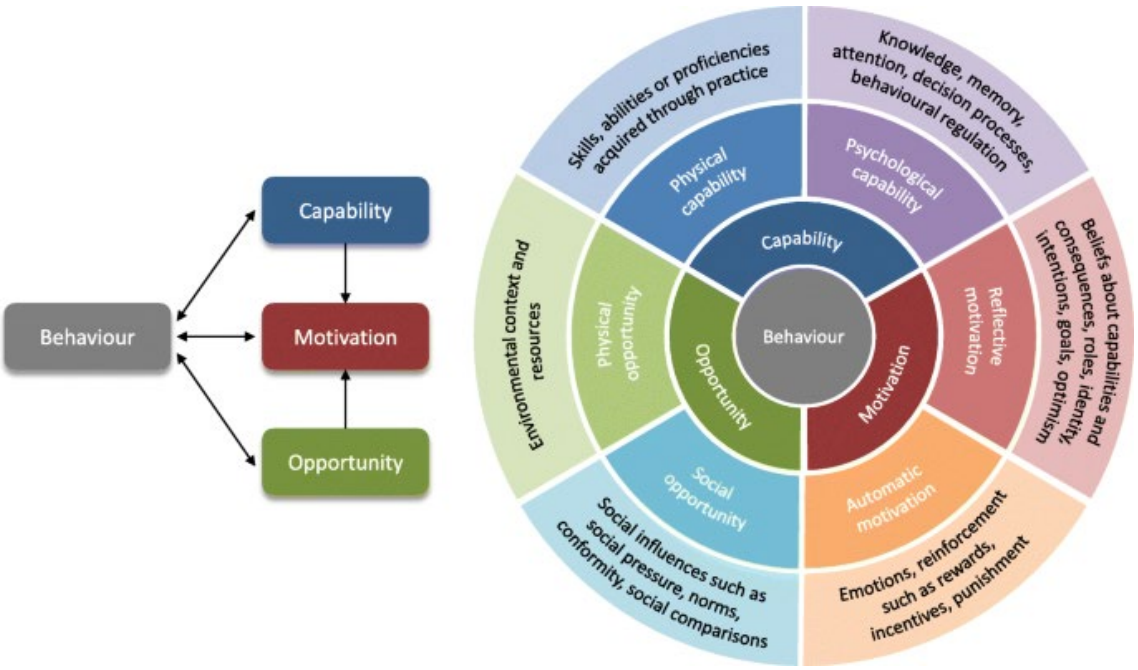

Figure 17. *COM-B model and Behaviour change wheel* (26)

User personas are a commonly employed tool in user experience (UX) design. They consist of descriptors of different individuals based on real user patterns, focusing on how they interact with products related to a specific context (e.g. medication routines). Adapted user personas with the COM-B model were consequently created to guide the author towards shaping proposed innovations for their target audience and build empathetic understanding with the end-users.

Finally, insights generated from the previous stage were mapped and categorised using thematic analysis. This method allowed the author to identify literature patterns and consolidate the gathered data into workable themes.

2.2.3 Develop

The purpose of this stage is to produce potential solutions through ideation and brainstorming.

As outlined by IDEO in Figure 18, brainstorming is an effective method for generating and aggregating multiple concepts. The outcomes from our thematic analysis led to the identification of several opportunity areas for potential design solutions. These outcomes were established as a foundation for the brainstorming session.

Following this stage, an agile methodology approach was adopted, where end-user feedback was continuously gathered and reintroduced throughout the development cycle (27). This iterative approach allows for meaningful collaboration between designers, developers, and stakeholders, aiding in speed and flexibility during the product development process.

Consequently, three concepts were identified as the focus for further iteration and development. We also considered current technological limitations and the feasibility of building a working prototype during our two-year research.

Application wireframes and early mockups were designed using rapid prototyping to create functional, low-to-medium fidelity builds suitable for desirability and usability testing.

Figure 18. *IDEO: Rules of brainstorming* (28)

A co-design workshop was organised for participants to evaluate the proposed design concepts, aiding in selecting a solution for further development. A proof-of-concept prototype was then built and presented as the proposed final solution to our design challenge.

2.2.4 Deliver

This stage is aimed to build, test, and iterate on the most promising ideas to implement a final solution within a healthcare environment.

The final solution selected in the previous stage was then subjected to further testing to improve and prepare our product for distribution. Product desirability was evaluated by measuring click-throughs and user retention on a product launch website. High-fidelity mockups were presented to provide website visitors with a better idea and understanding of the design solution.

Product usability was assessed during a demo workshop, observing how participants interacted with the product and recording any difficulties they experienced for future iterations.

A business model and product roadmap were then completed to identify the components required to implement our product, including key performance metrics, value proposition, cost structures, and potential revenue streams.

Finally, the overall proposed solution was assessed for appropriateness and suitability for market adoption utilising the evaluation methods recommended by our literature review.

2.3 Ethical Approval

This project was conducted as a service evaluation and quality improvement project. The project-lead is a clinical staff member working in the North West London Healthcare NHS Trust, where the project was based.

This project followed local Trust Quality Improvement and Clinical Governance procedures within the North West London Healthcare NHS Trust.

Ruth Nicholson, the Head of Research Governance and Integrity at Imperial College London, confirmed that this project satisfied the requirements of a service evaluation and subsequent quality improvement project and required no formal ethical approval through NHS REC or the Research Office (see Appendix **C** for details).

3 Discover

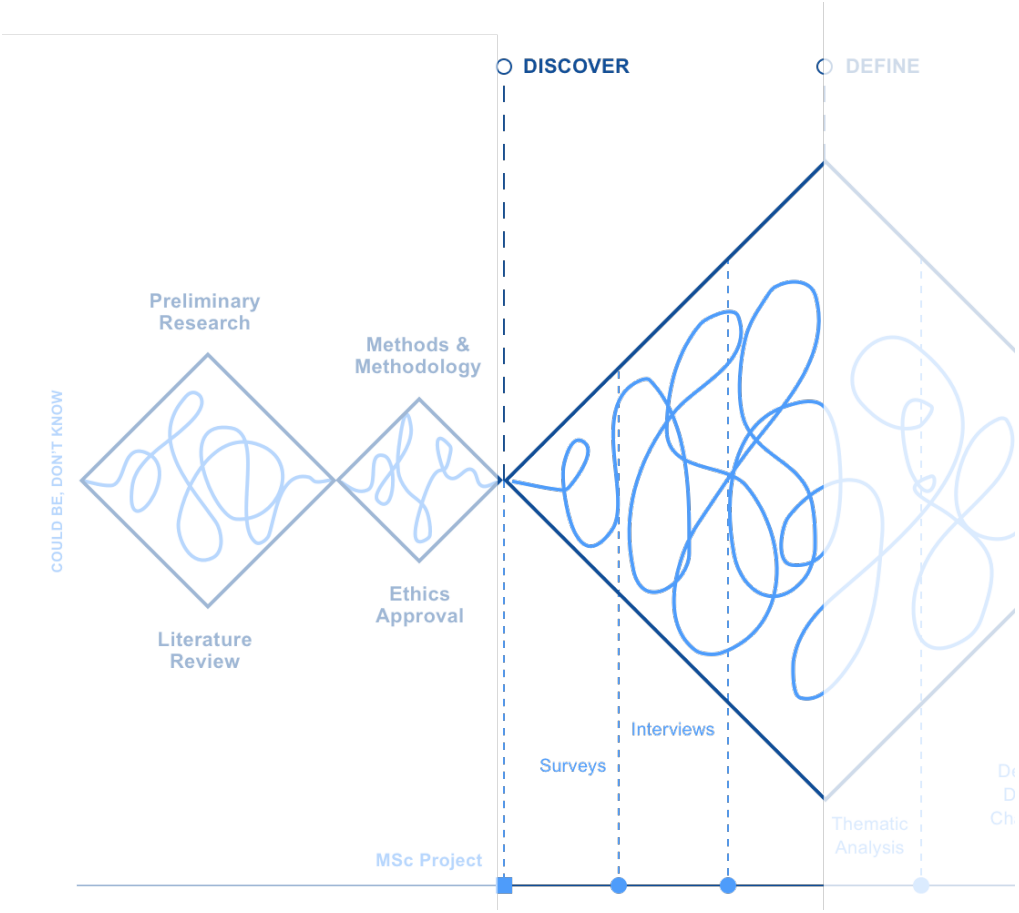

Figure 19. *Discover Process*

3.1 Aims

This dissertation aims to utilise a design thinking approach to identify the challenges patients face with medication compliance issues and design an intervention to improve adherence to medication regimens.

3.2 Literature Review

The research papers included in our study and the recurring themes identified through our analysis are shown in Table 1 on the following page.

Title	Author(s)	Year	Description	Thematic analysis
British South Asian Patients' Perspectives on the Relevance and Acceptability of Mobile Health Text Messaging to Support Medication Adherence for Type 2 Diabetes: Qualitative Study (29)	Prinjha et al.	2020	67 patients participated in a series of focus groups exploring the perceptions and views of mobile devices and text messaging services in managing medication regimens.	Adherence Factors Digital innovation Health Outcomes Suggestions
A qualitative study of cardiac rehabilitation patients' perspectives on taking medicines: implications for the 'medicines-resistance' model of medicine-taking (30)	White et al.	2013	15 interviews were conducted with patients who had completed a cardiac rehabilitation programme. The study aimed to examine the patients' experiences with medication regimens.	Adherence Factors Health Outcomes Limitations Suggestions
Shared decision making and experiences of patients with long-term conditions: has anything changed? (31)	Kayyali et al.	2018	319 patients participated in a mixed-method study evaluating the effects of shared decision-making on medication compliance. The author explored the introduction of medication counselling through a series of surveys and interviews.	Adherence Factors Health Outcomes Limitations Suggestions
Factors Associated With Nonadherence to Antiretroviral Therapy Among Young People Living With Perinatally Acquired HIV in England (32)	Judd et al.	2020	261 patients with HIV were surveyed and interviewed to explore the prevalence of medication non-adherence and examine the reasons. Medication compliance was also measured using objective laboratory tests.	Adherence Factors Health Outcomes Suggestions

Title	Author(s)	Year	Description	Thematic analysis
Non-adherence to antihypertensive medication is very common among resistant hypertensives: results of a directly observed therapy clinic (33)	Hameed et al.	2015	56 patients were monitored in a direct observation clinic to differentiate patients with poor medication compliance and those with treatment-resistant hypertension.	Adherence Factors Health Outcomes Suggestions
Improving medication adherence in stroke survivors: the intervention development process (34)	Crayton et al.	2018	The authors mapped existing data from systematic reviews to the behaviour change wheel to identify potential intervention options that can be utilised to improve medication adherence in stroke patients.	Adherence Factors Limitations Suggestions
Supporting respiratory patients in primary care: a qualitative insight from independent community pharmacists in London (35)	Hesso et al.	2019	23 pharmacists were interviewed regarding their experiences as healthcare providers and new technology – the Inhaler Compliance Assessment device – introduced to the monitor inhaler technique and medication adherence.	Adherence Factors Digital Innovation Health Outcomes Limitations Suggestions
Reasons for (non)compliance with intervention following identification of 'high-risk' status in the NHS Health Check programme (36)	McNaughton et al.	2015	29 semi-structured interviews were conducted with patients at high risk of cardiovascular disease. The study aimed at understanding the factors that influenced their adherence to medication and their understanding of the medication they were taking.	Adherence Factors Health Outcomes Suggestions

Title	Author(s)	Year	Description	Thematic analysis
Understanding alcohol-related liver disease patients' illness beliefs and views about their medicine (37)	Presky et al.	2018	An observational cross-sectional survey on 159 patients with alcoholic liver disease was conducted over 12 months to understand their views about the medications they were taking, their perception of their illness and their reported compliance.	Adherence Factors Health Outcomes Suggestions
Adherence to medication and self-management in stroke patients (38)	Chapman et al.	2014	The author conducted a systematic review of 6 randomised control trials and quasi-experimental trials on the self-management techniques applied by stroke patients.	Adherence Factors Health Outcomes Suggestions
Understanding pregnant women's adherence-related beliefs about Nicotine Replacement Therapy for smoking cessation: A qualitative study (39)	McDaid et al.	2020	18 patients participated in semi-structured interviews regarding their experiences with nicotine replacement therapy. The study examined motivations to start treatment, expectations and concerns about the treatment.	Adherence Factors Health Outcomes Suggestions
The impact of community pharmacy-led medicines management support for people with COPD (40)	Alton et al.	2018	45 patients were involved in a service improvement project assessing the impact of personalised medication support led by a pharmacist in the community. The study utilised a standardised assessment scoring tool to compare health outcomes from the intervention.	Adherence Factors Health Outcomes Innovation Suggestions
Looking at medication adherence: An evidence review (41)	Chapman, S	2017	A Cochrane overview of 75 systematic reviews was conducted, investigating recurrent themes to improve medication compliance.	Adherence Factors Suggestions

Title	Author(s)	Year	Description	Thematic analysis
When Is Forgetting Not Forgetting? A Discursive Analysis of Differences in Forgetting Talk Between Adults With Cystic Fibrosis With Different Levels of Adherence to Nebulizer Treatments (42)	Drabble et al.	2019	Interviews were conducted with 18 adults with cystic fibrosis. The study aimed to explore the factors that contributed to patients' forgetting' to take their medication.	Adherence Factors Health Outcomes Suggestions
Electronic monitoring of adherence to inhaled corticosteroids: an essential tool in identifying severe asthma in children (43)	Jochmann et al.	2017	93 participants with known asthma were observed using an electronic monitoring device (Smartinhaler). The study hypothesised that electronic monitoring could separate patients with poor adherence from those with severe asthma requiring further medication optimisation.	Adherence Factors Digital innovation Health Outcomes Limitations

Table 1. *Literature Review: Summary*

3.2.1 Analysis

Medication Non-adherence Outcomes

The advancements in pharmaceutical and medical technology have led to numerous breakthroughs in modern-day medical practice. However, although medications play an integral role in patients with long-term health conditions, non-adherence has increased hospital admissions and economic costs for society (37). Studies have estimated that 33–50% of prescribed medications for long-term conditions are not taken as recommended (40).

Moreover, the diagnosis and management of difficult-to-treat conditions, such as severe asthma (43) and treatment-resistant hypertension (33), are complicated by poor adherence, highlighting the need for early recognition of such patients to optimise their medical management.

Patient behaviours

White et al. (2013) initially set out to investigate four types of behaviours patients display when prescribed medications by their physicians:

- Passive accepters: accept their prescribed medications without resistance
- Active accepters: question their prescriptions and work with their physicians to understand and tailor their medication regimen for individualised care
- Active modifiers: accept that they require medications but modify their regimen after self-evaluation, and
- Complete rejecters: reject their need for medication

However, White found that the distinctions between these categories were not always apparent. For example, those initially classified as 'complete rejecters' did not always wholly reject their prescribed regimens and often preferred to take as few as possible. Furthermore, White noted that more than half the patients interviewed expressed concerns about taking their medication, despite adhering to their regimens as prescribed. Despite this issue, many of these patients often feel that they had no choice other than to continue taking these medications because there were no other practical options.

Furthermore, Judd (32) determined that up to 68% of patients in their study (of 106 participants) were frequently missing doses of medication. In addition to missing medication due to forgetfulness or modifying regimens, patients in the study also quoted instances where they did not want others to know of their condition (23%) and feelings of denial towards their diagnosis (24%) as reasons why they missed medication doses.

During our literature review, several recurring themes became evident amongst patients with medication non-adherence. The following themes relating to medication non-adherence, described by Judd (32), McNaughton (36) and Presky (37), are demonstrated on the next page.

Base Theme	Sub-Theme	Examples
Adherence Factors	Consequences	Fear of side-effects
	Timeline	Forgetting to take medication on time Work/school schedules interfering with medication regimens
	Personal control	Fear of addiction to medication Lack of patient-centred care
	Illness comprehension	Denial of illness Denial of the severity of condition necessitating medication
	Medication counselling	Unclear purpose of medication Confusing guidance regarding medication regimens

Table 2. *Literature Review: Recurring Themes*

Evaluation of Existing Solutions

Ten studies described the use of healthcare innovations to improve medication compliance. These approaches ranged from pharmacist-led medication reviews in the community (41) to Smartinhaler asthma devices for medication tracking (43).

The APEASE criteria, described by Crayton (34), evaluate interventions based on the following traits:

- Affordability: is it acceptable to all key stakeholders?
- Practicability: can it be implemented as designed?
- Effectiveness & cost-effectiveness: is it effective in achieving the objectives?
- Acceptability: how far can it be afforded when delivered?
- Side-effects & safety: does it lead to unintended adverse outcomes?
- Equity: does it change differences between sectors of society?

Consequently, an analysis of the solutions found in our literature review utilising the APEASE criteria is shown below (Figure 20).

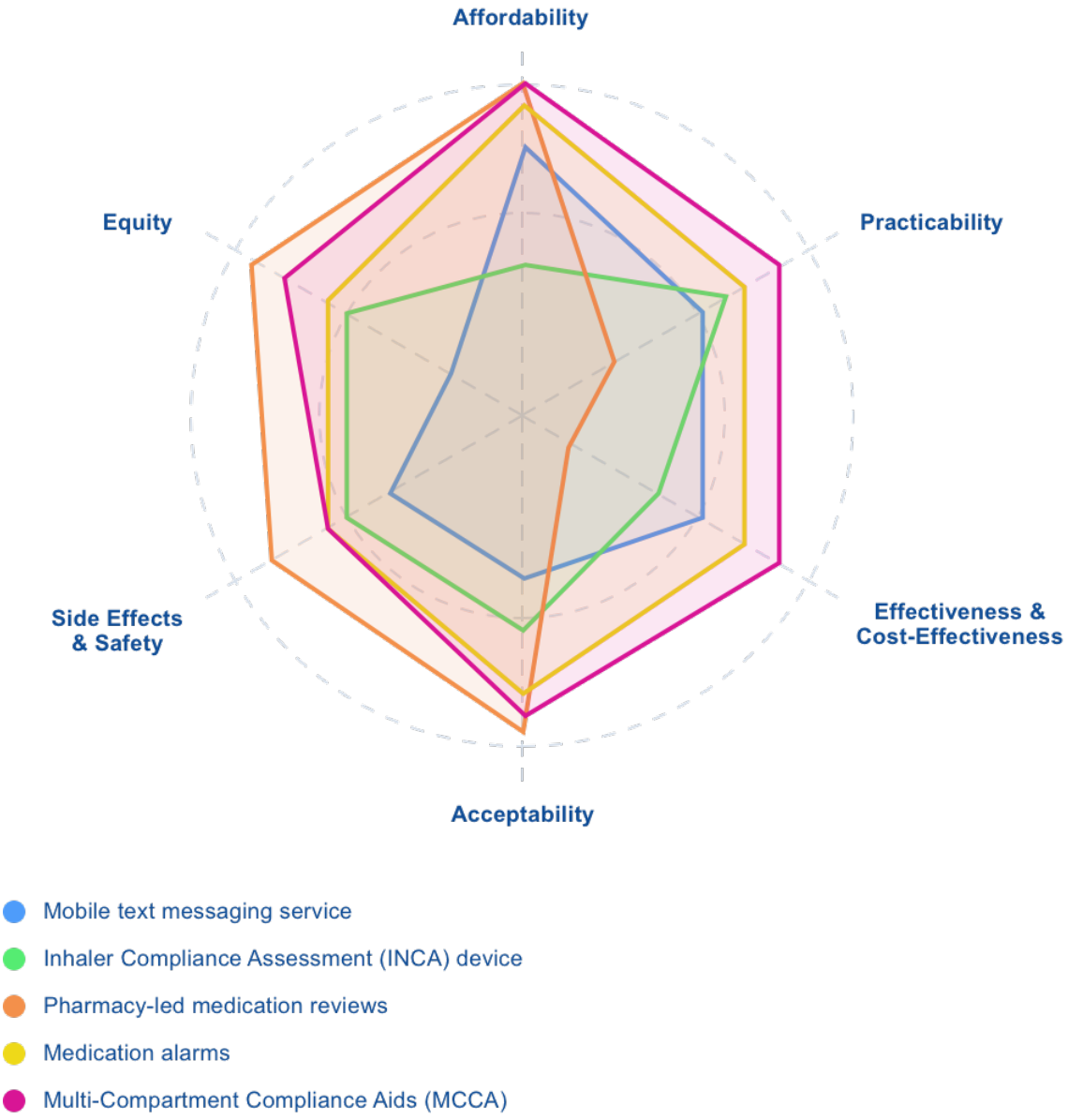

Figure 20. *Evaluation of existing innovations utilising APEASE criteria*

Key Stakeholders

We established two groups of key stakeholders for healthcare innovation (8,29,34).

Healthcare professionals are vital stakeholders in healthcare innovation. Within a community setting, these experts include General Practitioners who review and establish a treatment plan, community pharmacists who issue medications and the Clinical Commissioning Groups within the NHS who fund the services and treatments offered in a local area.

Patients and their carers form the second group of key stakeholders. Patient-centred care is essential to the NHS, and any tools or decisions made in the community affect them directly.

The complete list of stakeholders as identified by our literature review is demonstrated below.

Figure 21. *Stakeholders for healthcare innovation in the community*

Conclusion

Our literature review validates the problem of medication non-adherence and highlights the challenges faced by patients when prescribed medication regimens.

Although no single solution can address all the issues these patients may face, interventions described by our studies demonstrated effective methods in aiding compliance and benefiting health outcomes. These interventions were particularly effective when addressing patient-centred care and medication counselling.

These findings prompted further research into patients' behaviours when taking medication and designing strategies to manage their regimens.

3.3 Survey

A total of **52** individuals responded to our survey, consisting of patients and their carers in the UK.

97% (50) of respondents answered 'Yes' to taking medication for a long-term health condition. The number of medicines these participants took regularly varied from '1 tablet a day' to '16 tablets four times a day'.

The majority of our participants (92%; 47) had missed doses of medication due to forgetfulness. Furthermore, 98% (51) of our participants admitted to interrupting a course of medication before completion. In addition, 77% (40) of participants reported having discontinued medication because of their side-effects, and 73% (38) stated that they had broken their prescribed regimen because they felt that their condition had improved.

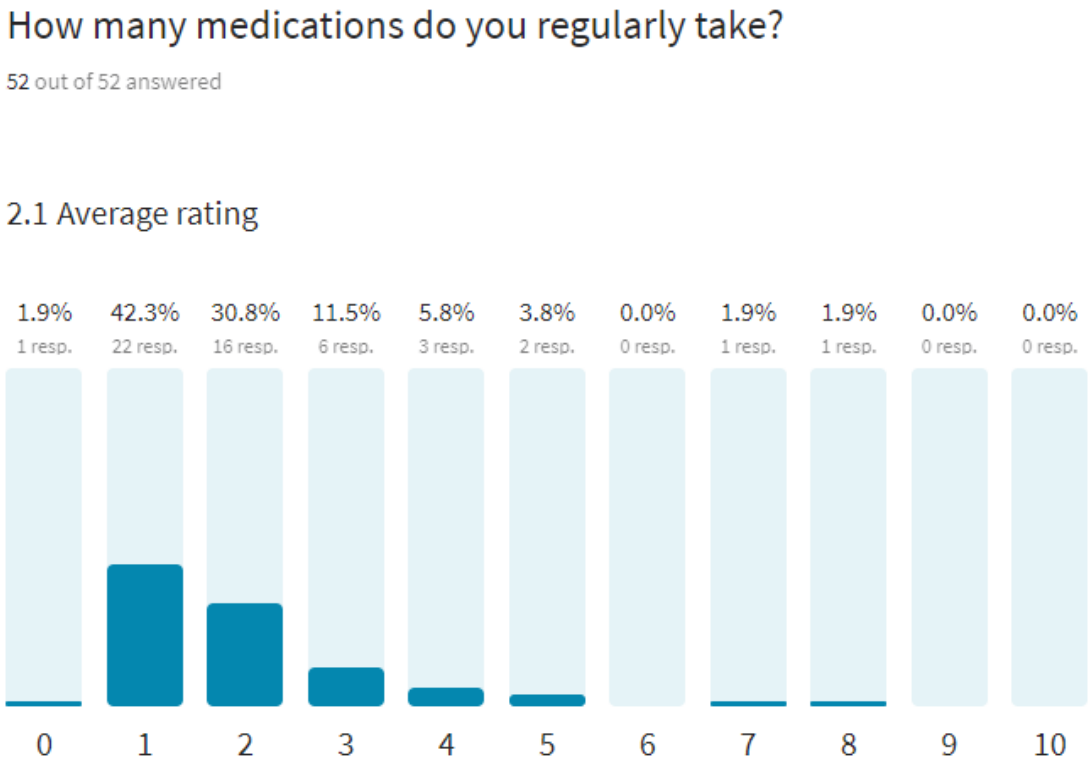

Figure 22. *Survey Results: Number of medications*

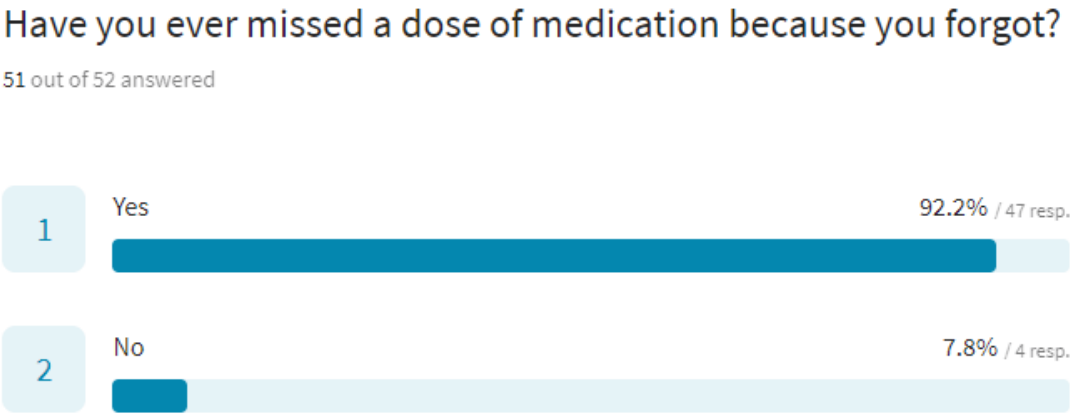

Figure 23. *Survey Results: Forgetting medication courses*

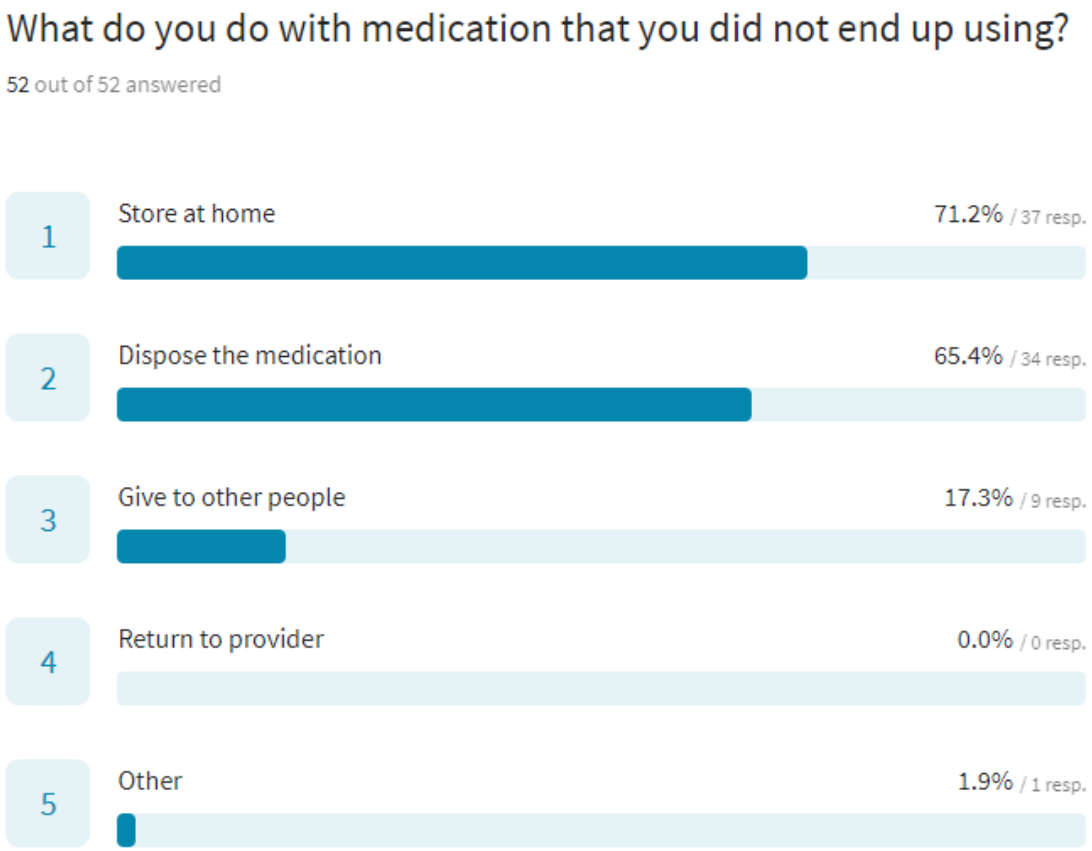

Figure 24. *Survey Results: Disposing of medications*

The discontinued medication was often stored at home (71%; 37 participants) or disposed of (65%; 34 participants), with a small proportion of medication (17%; 9 participants) given to other people. Interestingly, none of the unused medication was ever returned to the healthcare providers as reported by our survey respondents.

A summary of our survey results can be seen in Figures 22-24.

Lastly, our survey prompted users to describe what they felt would help them take their medication regularly. A list of common themes with their responses is shown below.

Theme	Comments
Medication alarms	Felt that they were annoying and intrusive
	Feels that they helped with developing a routine
	Feels that the integration with their phones assisted with their compliance
Shifting responsibility to family/carers	Feels that they require support from their family in order to keep going with medication regimens
	Never misses medications because has a carer to help with administration
Medication counselling	Feels that they would not discontinue courses/miss fewer doses if they understood why they were taking the medicines
	Feels that compliance would be better if they knew of the side-effects before they began taking the medicines
	Feels that they did not know enough about the side-effects/consequences of discontinuing courses early
	Feels they did not understand why they were on so many different medicines
	Feels that they did not need to take half of their medicines so discontinued them
	Unsure what to do after accidentally missing a dose of medicine. Do they take the missed dose now or skip it until the next administration cycle?

Table 3. *Survey Results: Common themes*

3.4 User Interviews

Ten participants were invited for a series of user interviews to explore their experiences with the self-administration of medication. Interviews followed a semi-structured format, allowing for open-ended questions with the flexibility to examine reoccurring themes further. The focus of these interviews was self-administration strategies that patients utilised to aid in their medication compliance.

Notes were taken during the interview and later thematically analysed and coded.

Self-Medication Strategy

Our participants regularly took many different medication types, including:

- Oral tablets
- Intramuscular injections
- Subcutaneous injections
- Subcutaneous infusion pump
- Inhalers
- Analgesia patches

Five participants mentioned the use of a dosette box or blister pack in managing their medications. They described these tools as a helpful way of remembering when to take medication and keep track of any missed doses.

Three participants used mobile applications on their phones to set alarms and reminders for their medication regimen.

One participant noted that they found it particularly beneficial to have regular check-ups with their General Practitioner for medication reviews and discuss any concerns they had over their regimens.

Four participants discussed how they integrated their medication regimens into their daily routines. For example, one participant would place their medication boxes next to the bathroom mirror, so they would be reminded of it when they brushed their teeth in

the morning. Another participant put their medicines in the kitchen, associating them with meals.

Problems with Medication

During our interview, our participants raised several concerns regarding their prescribed medication regimens.

One participant noted that new medication and tablets were often a cause of confusion. They described not knowing 'what to take and when' and mentioned the lack of medication counselling as a cause.

Another participant had difficulty planning holidays and trips due to the number of medications and their limited supply. They mentioned that they were often unsure about whether they had sufficient doses to take when travelling and feared running out.

Lastly, one participant suggested that medication packaging be made more apparent and accessible because they often struggled to understand which medicines they were taking due to their colour blindness.

4 Define

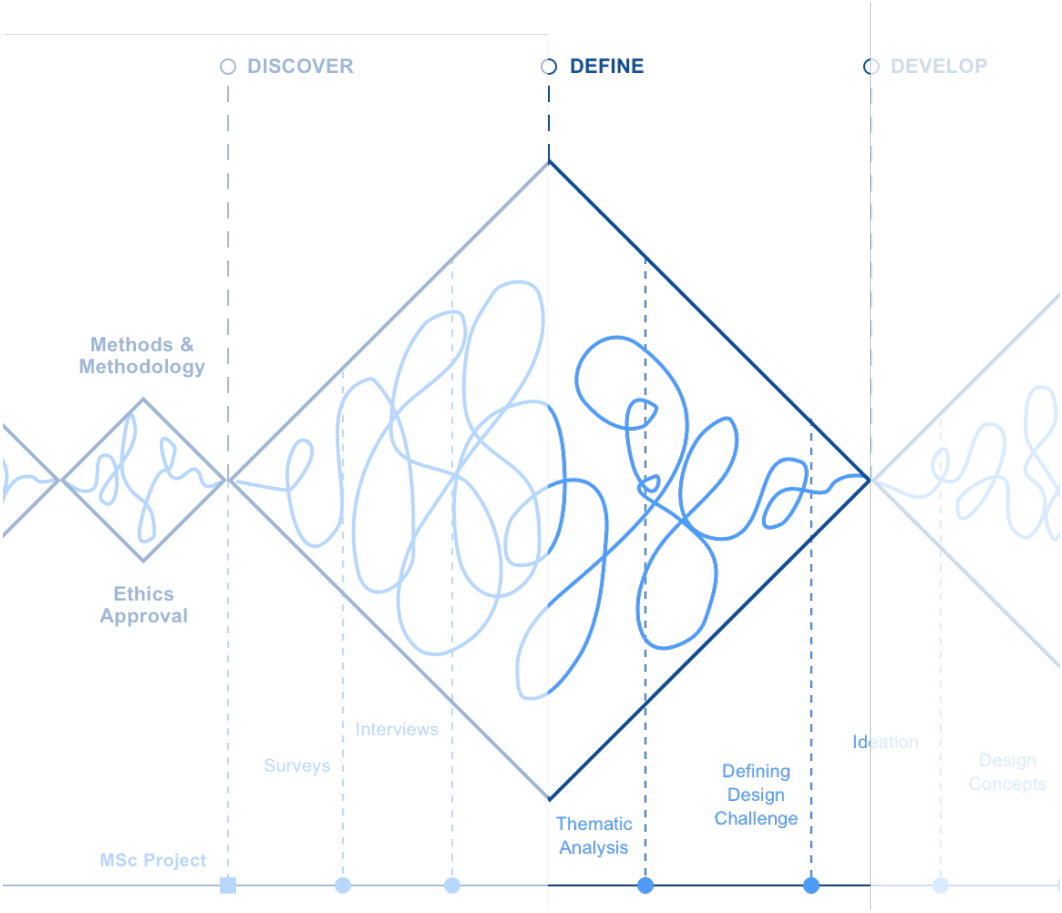

Figure 25. Define process

4.1 Approach

This section aims to summarise the insights gathered in the previous phase through primary and secondary research to identify themes and highlight opportunities for innovation.

Research Question: Can design thinking help understand patients with medication compliance issues and generate insights to improve healthcare outcomes?

- To understand medication compliance and methods to support adherence to medication regimens through a literature review.
- To identify shared behaviours and challenges in patients with medication compliance issues through patient interviews and surveys.
- To develop a model for evaluating medication compliance in new and existing innovations.
- To design and test a solution that improves medication compliance in patients in the UK, including insights into industry attractiveness and sustainability of the product.

4.2 Insights

The previous phase validated the need to promote medication compliance to improve health outcomes. We found that up to half of prescribed medications were not taken as prescribed, leading to increased hospital admissions and mortality. The non-adherence to medication regimens also made it difficult for clinicians to differentiate between severe and treatment-resistant diseases.

Our research demonstrated patients' different behaviours when prescribed medications, such as active accepters and active modifiers. For the purpose of this study, our design challenge focuses on medication compliance in patients who are

already taking medications regularly, particularly in those who occasionally miss medication doses or alter their medication regimens.

Based on our research, three patient personas were designed to represent the different user types we may encounter (Figure 26-28). The COM-B model was used to identify the needs of each individual for them to perform the behaviour of taking medications regularly (26).

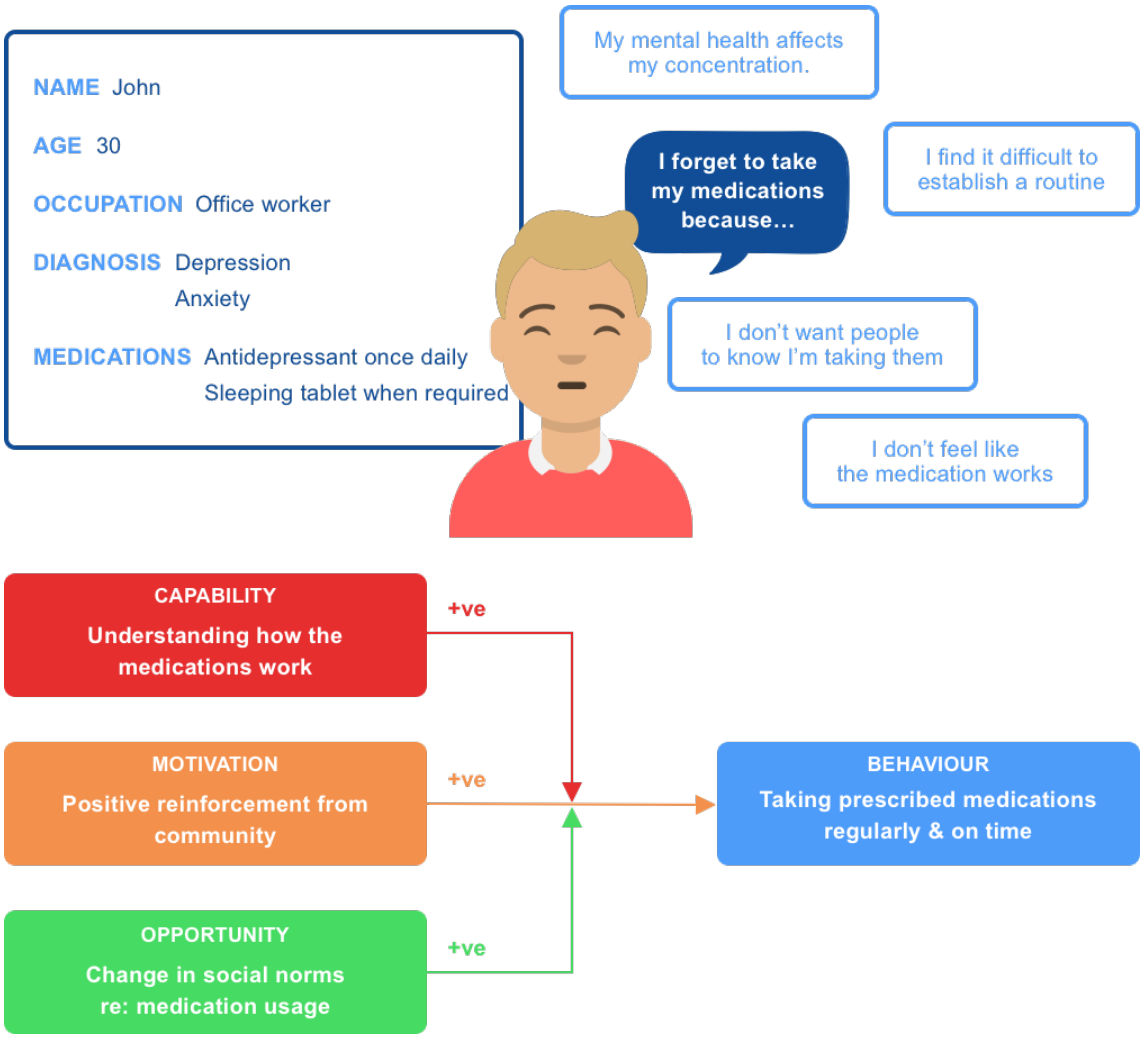

Figure 26. *User Persona A: 30-year-old John*

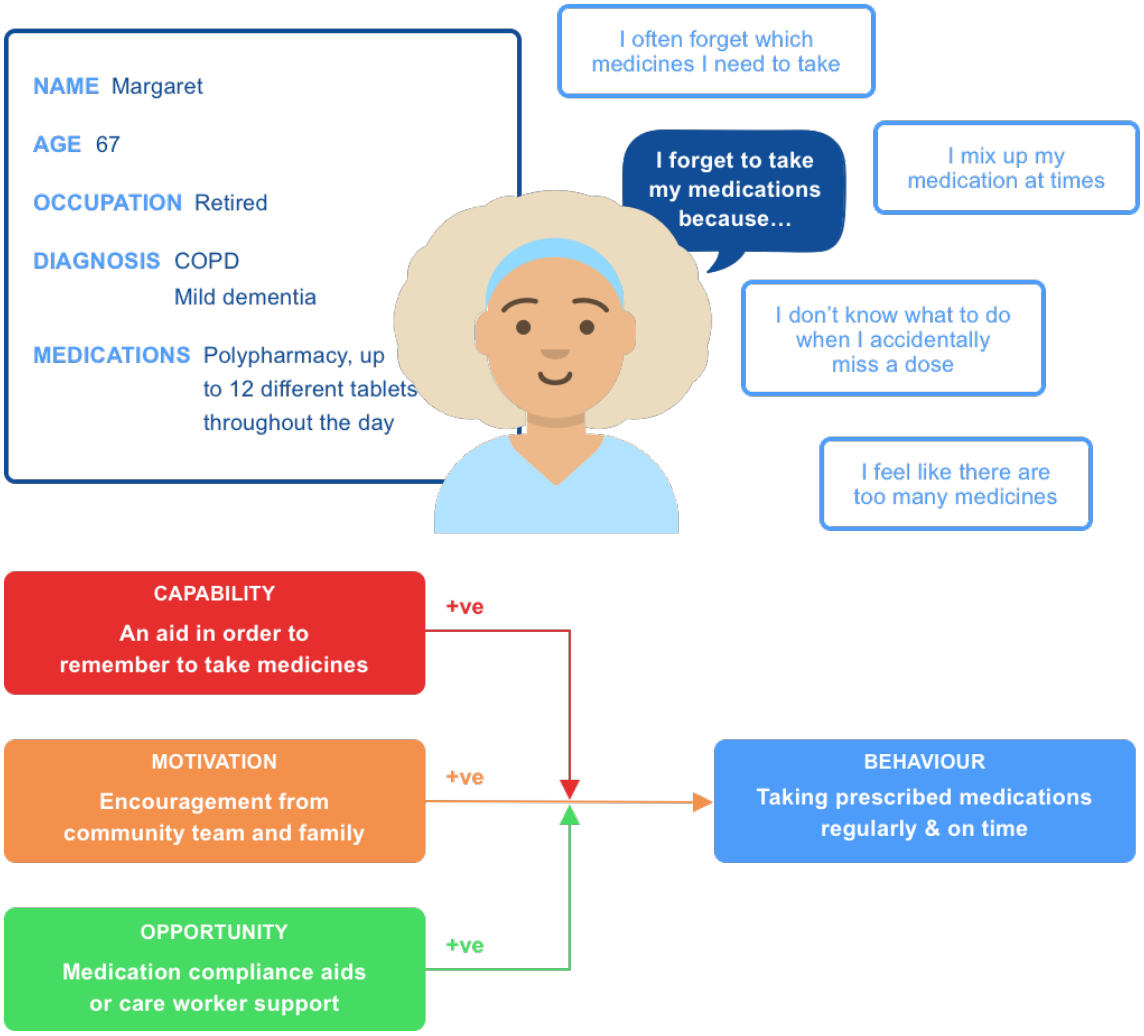

Figure 27. *User Persona B: 67-year-old Margaret*

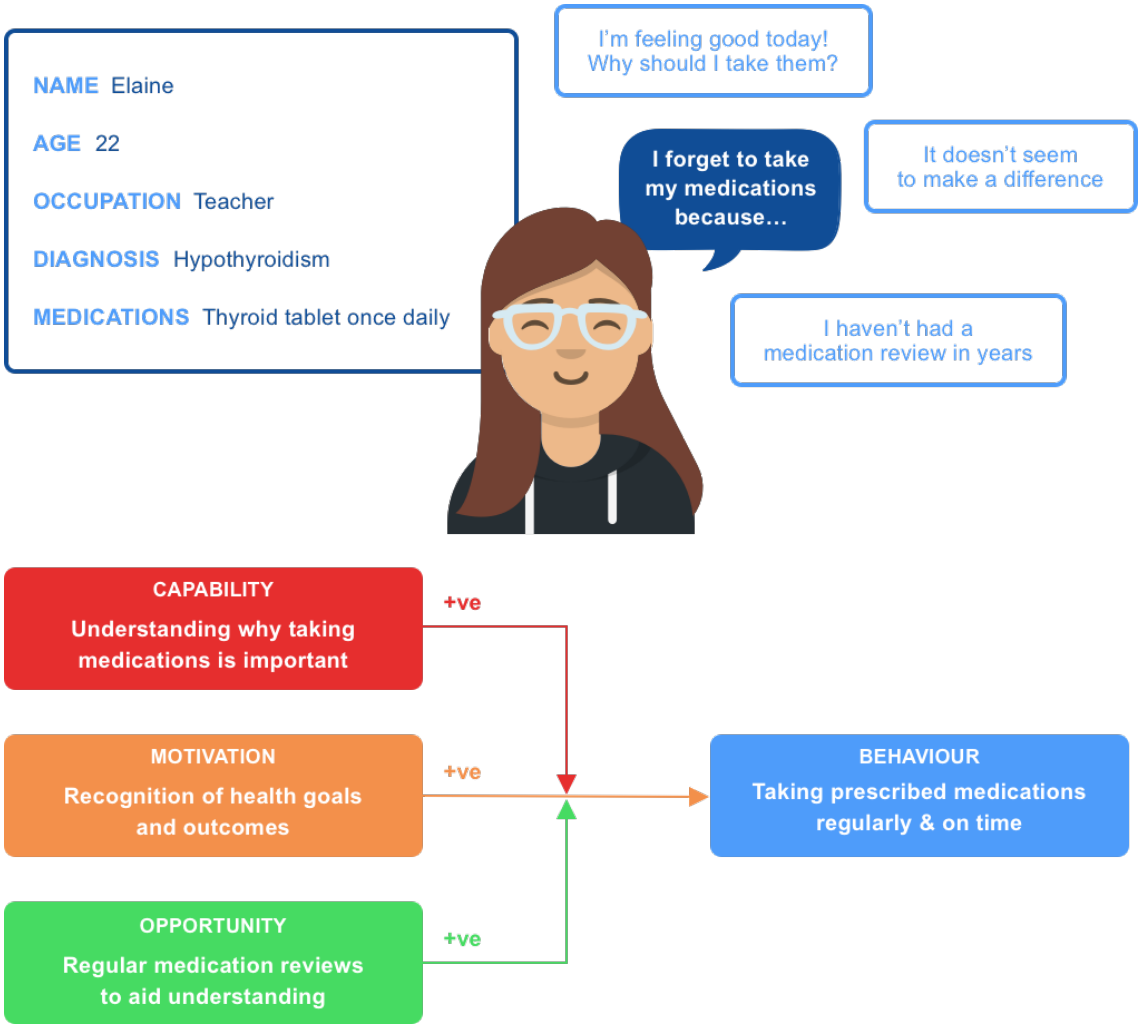

Figure 28. *User Persona C: 22-year-old Elaine*

4.3 Thematic Analysis

Our research insights were mapped and categorised into the following themes:

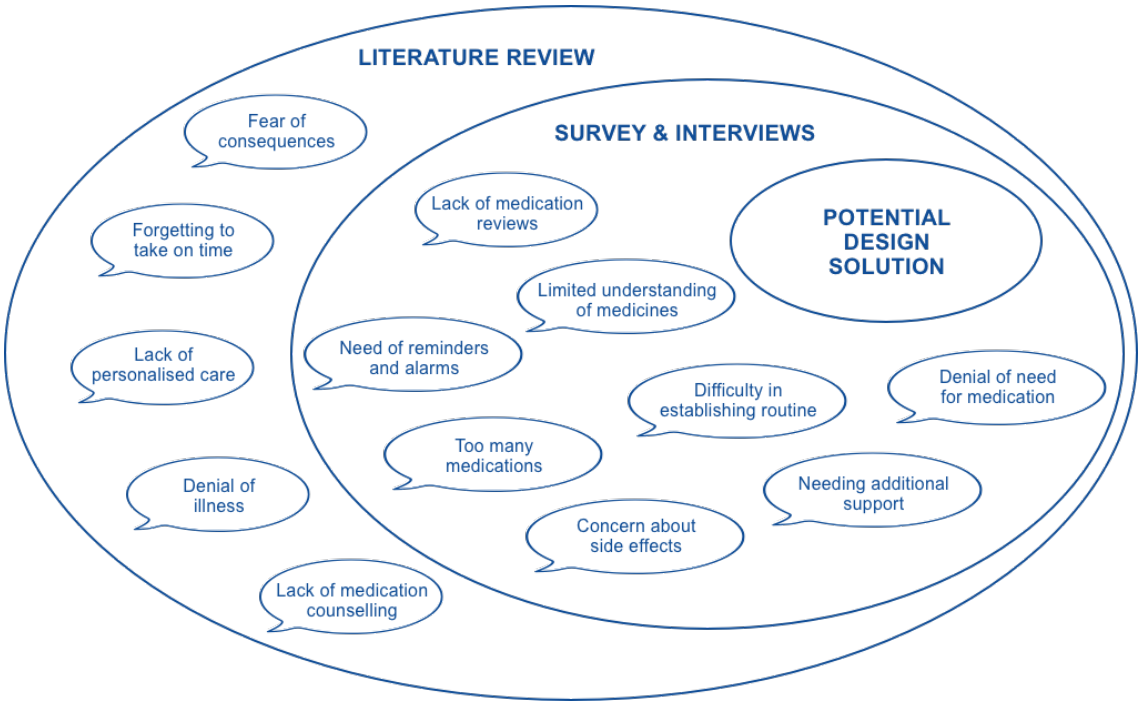

Figure 29. *Research Insights grouped by Themes*

4.4 Design Challenge

How might we design an intervention for patients to promote understanding of their medications and the necessity for medication compliance?

How might we design an intervention for patients to promote medication administration tracking?

Key Requirements

Based on the APEASE criteria:

1 Affordability: Is it affordable for communities within the NHS?

2 Practicability: Can it be implemented and designed as intended?

3 Effectiveness and cost-effectiveness: Will it be effective in improving medication compliance?

4 Acceptability: The intervention must be agreeable to key stakeholders (healthcare professionals and patients)

5 Side-effects and safety: Are there any potential adverse outcomes?

6 Equity: Is this intervention fair to all members of society?

AACTT Framework

Finally, the AACTT framework was used to specify our target audience and their behaviour (44). This framework ensures that we address the key behaviours, stakeholders, and particular action settings when designing an intervention (Figure 30).

Figure 30. *AACTT Framework*

5 Develop

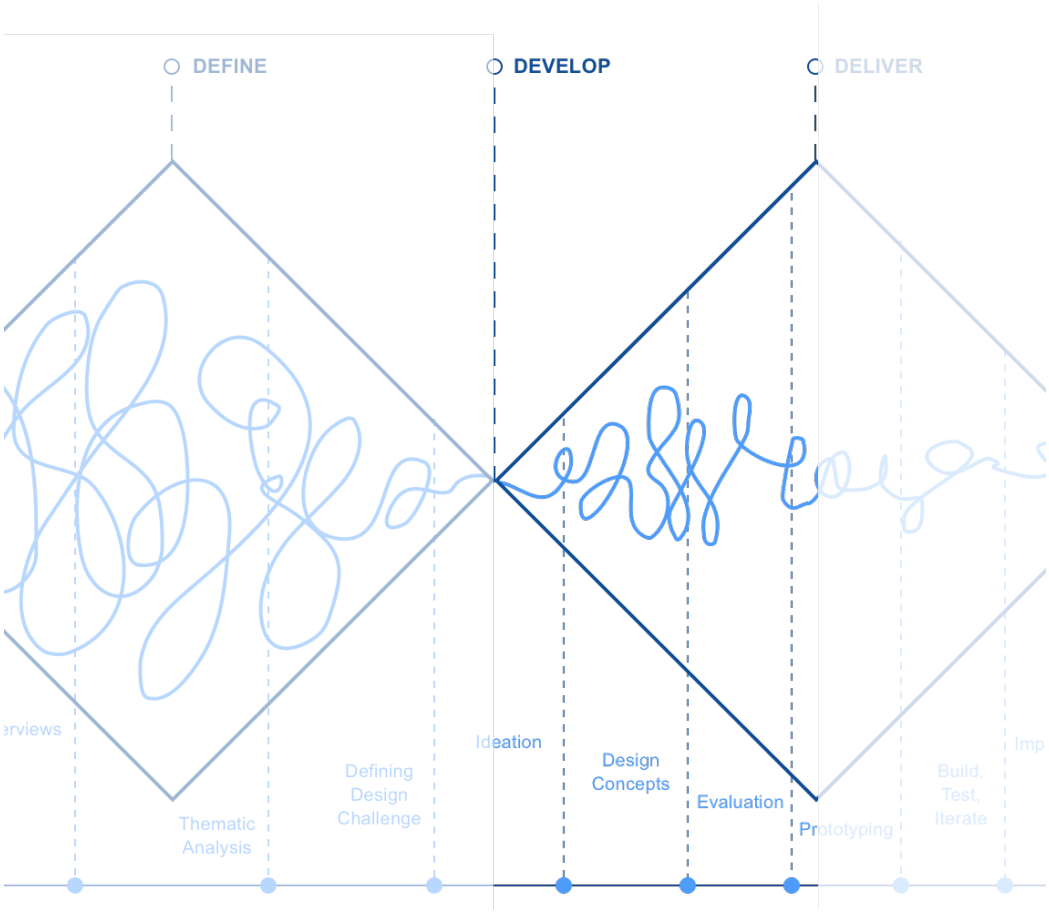

Figure 31. *Define process*

5.1 Approach

This section aims to explore the potential solutions to improving medication compliance in the community. The design challenge defined in the previous chapter will guide our ideation and brainstorming process, leading to the selection of a final concept for further iteration and delivery. Finally, the author presents the proposed solution through storyboarding, wireframing, and a proof-of-concept model.

5.2 Opportunity Areas for Potential Design Solutions

Medication compliance can be challenging to achieve when there are multiple confounding factors, such as limitations in physical and psychological capabilities to perform these tasks. Illnesses such as dementia can often affect an individual's memory, leading to forgetfulness and impacting their usual routines. Acute changes in health, such as a flare in irritable bowel syndrome, can also cause patients to take more medication than necessary in an attempt to treat their symptoms.

Although supportive tools such as medication alarms currently exist, this dissertation explores design concepts that would add value and intervene in instances when existing solutions could not.

The development process began with an ideation session. Prompted by strategy and workshop cards designed for the Healthcare & Design course (Figure 32), the author brainstormed and generated over 30 different innovative ideas to tackle medication compliance.

The author then identified three concepts based on our target audience and design challenge. These concepts each focused on a different area of opportunity within our thematic analysis and sought to improve medication compliance. Most importantly, the limitations of current technologies were considered during this process to create a working prototype through this research project.

Figure 32. *Healthcare and Design Workshop and Strategy cards*

Figure 33. *Brainstorming session*

5.2.1 Design Solution: Medication Info Deck

The **medication info deck** is a collection of patient-friendly cards that can be distributed to patients and their carers when medications are prescribed (Figure 34).

These cards aim to provide clear and concise information about patients' medications, removing the unnecessary jargon in standard medicine packaging and addressing their primary concerns.

Although medication boxes typically come with pre-packaged information leaflets, this information's layout and presentation often lead to missed vital information. These pre-packaged leaflets were redesigned to address patients' concerns by utilising recommendations from NICE BNF (7) and the clinicians involved in the project.

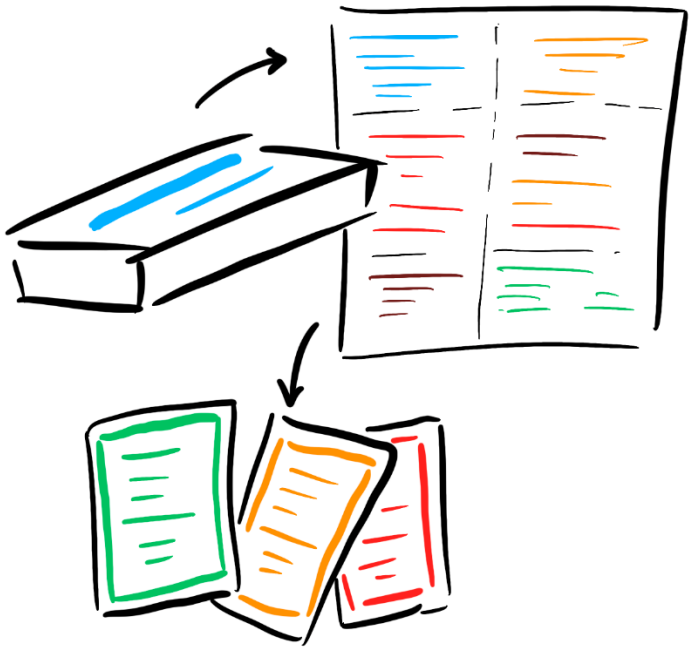

Figure 34. *Design Concept: Medication Info Deck*

This concept aims to clarify medication side-effects and the limited understanding of medicines that patients face. By focusing on improving knowledge and understanding about their medicines, this concept hopes to address any concerns patients may have and help them understand the need for good medication compliance (Figure 35).

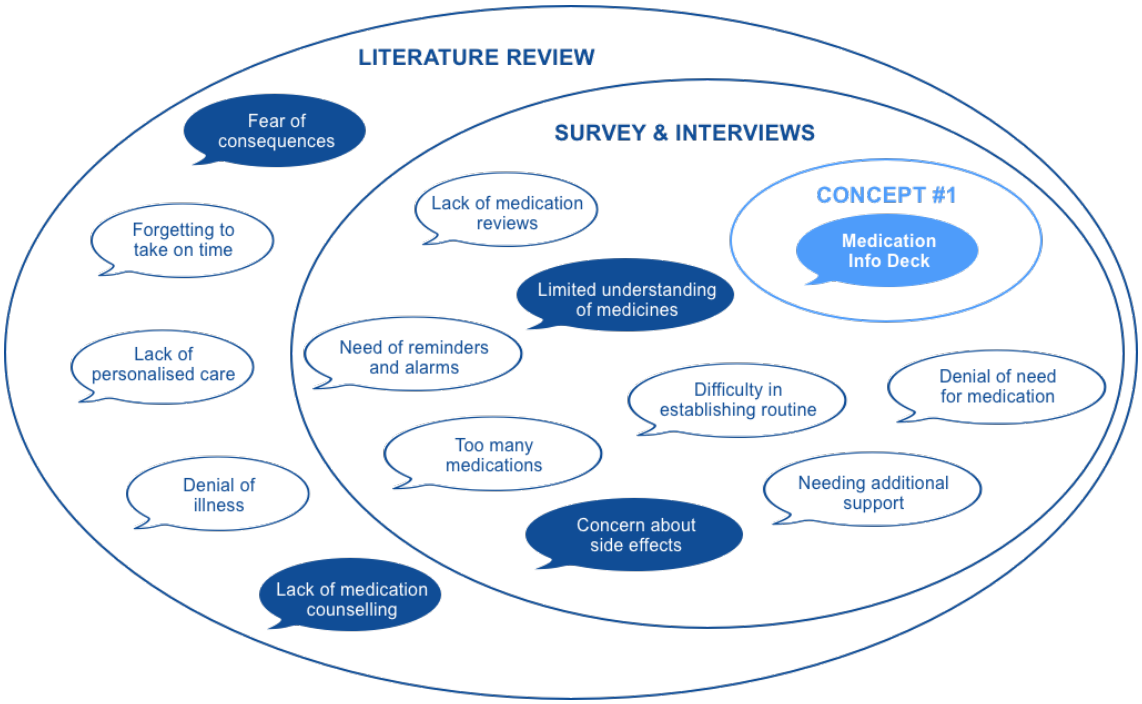

Figure 35. *Opportunity Area: Medication Info Deck*

5.2.2 Design Solution: Digital Pillbox

The **digital pillbox** is a device that can attach to existing dosette boxes that patients already use to track medication usage and build routines (Figure 37).

The aim is to incorporate e-ink technology into existing dosette boxes to track when each pill package is opened and the exact times when medication is taken. When a pill package is opened, the break in the conductive ink will notify a smartphone device, allowing for detailed medication tracking and personalised reminders.

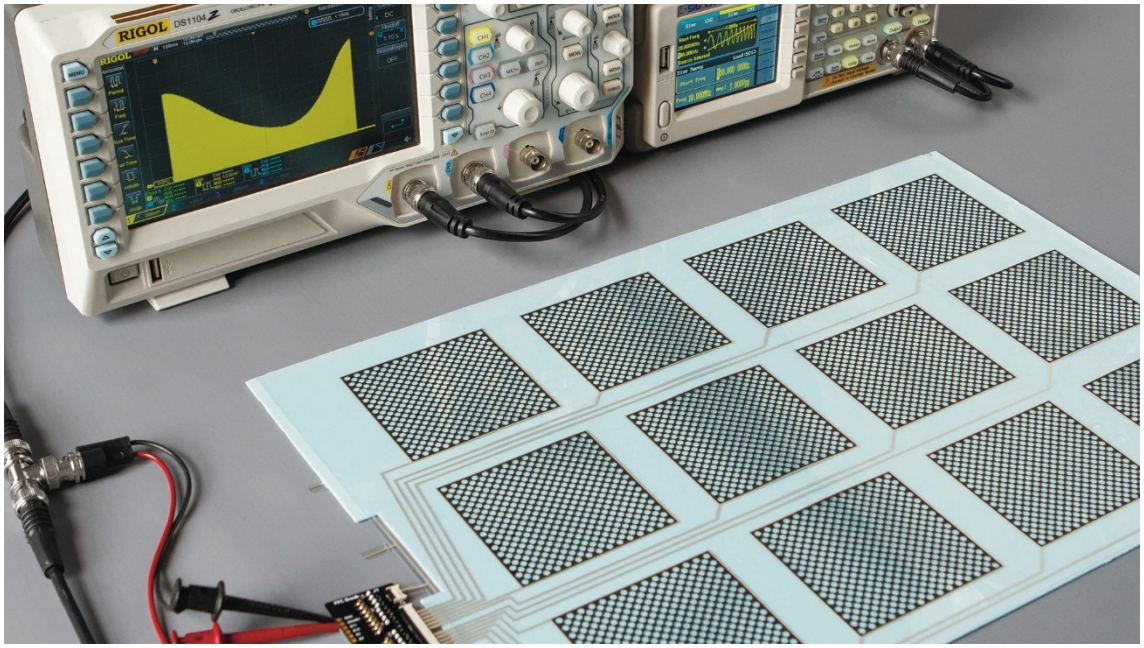

Figure 36. *Conductive ink technology* (45)

The adaptation of existing dosette boxes that many patients are already familiar with may aid in the adoption of this technology. The goal is for pharmacists to continue issuing standard pre-packaged dosette boxes with the integration of this new technology, allowing patients to continue with their existing routines whilst enhancing this experience with digital tracking.

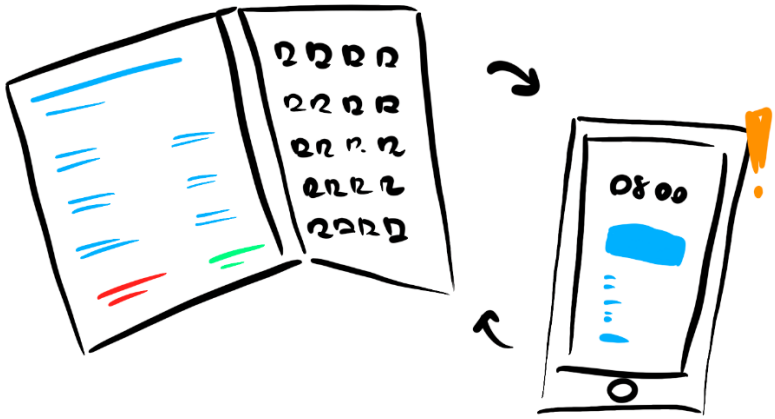

Figure 37. *Design Concept: Digital Pillbox*

This concept aims to help patients build a medication routine and assist in taking medications on time. An added benefit could include automated prompts for medication reviews when the patient reaches the end of their prescribed courses (Figure 38).

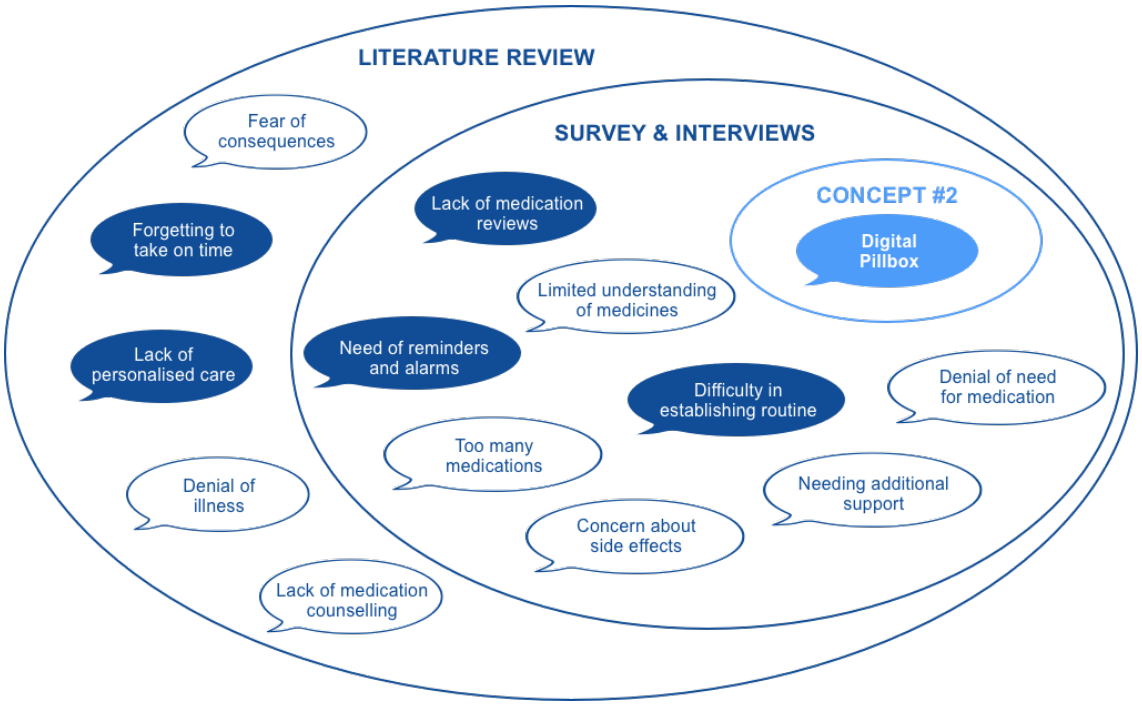

Figure 38. *Opportunity Area: Digital Pillbox*

5.2.3 Design Solution: Virtual Doctor

The **virtual doctor** is an artificial intelligence assistant that can conduct medication reviews automatically (Figure 39).

The aim is to provide access to regular medication reviews utilising guidelines and protocols that medical professionals currently use. These reviews would include dosage and timing adjustments to medication regimens.

The virtual doctor would be a digital application available on both smartphones and computers, allowing patients to discuss their concerns regarding their medication in an interactive manner.

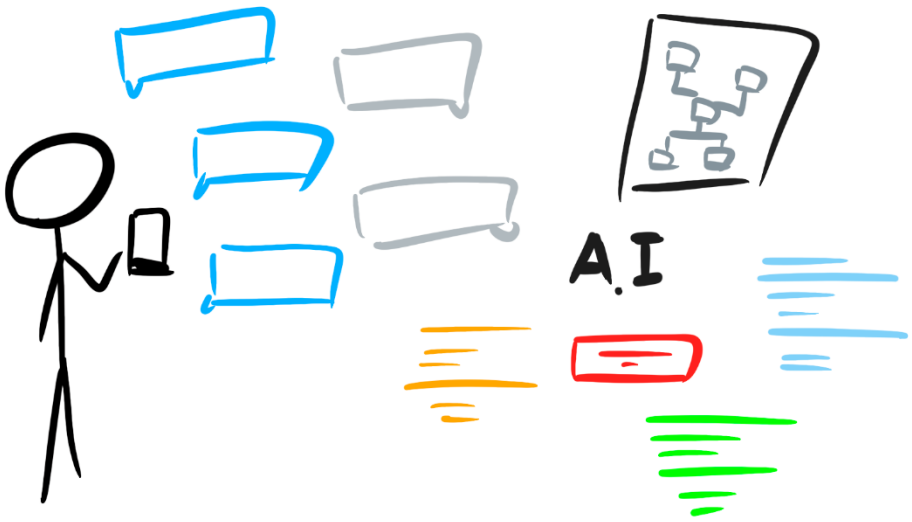

Figure 39. *Design Concept: Virtual Doctor*

This interactive experience would aid in delivering personalised care towards patients and help automate medication reviews in the community for patients who often struggle to obtain appointments with their general practitioners (Figure 40).

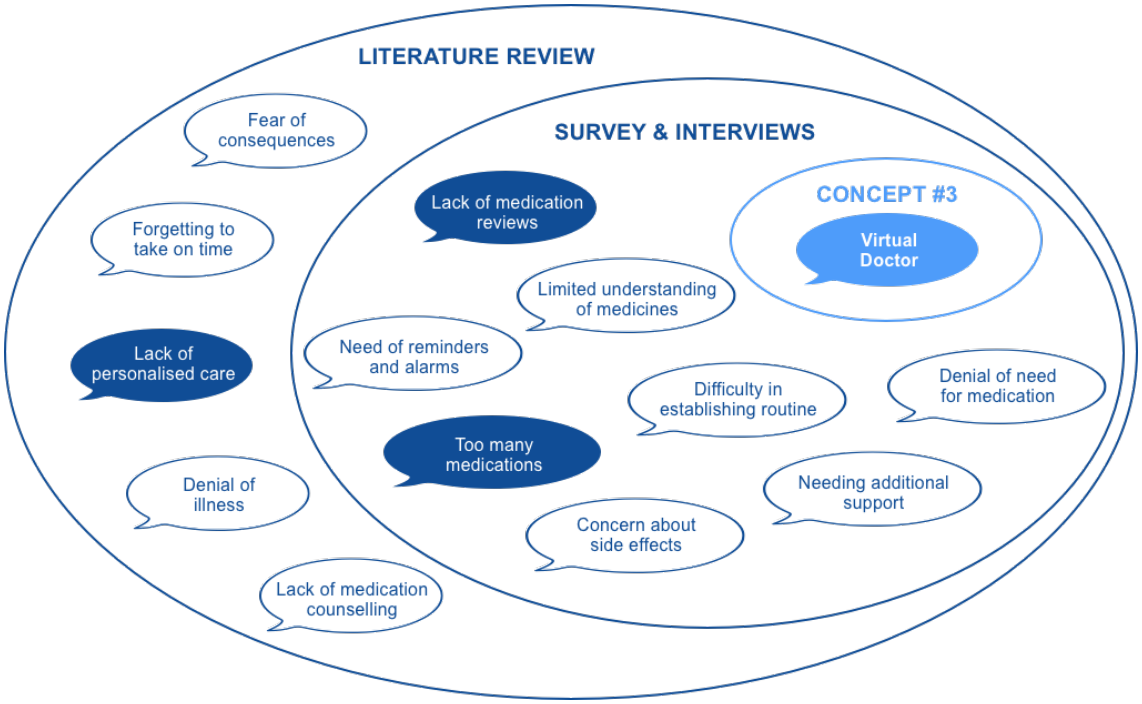

Figure 40. *Opportunity Area: Virtual Doctor*

5.3 Concept Prototyping

Initial prototypes were created in Sketch (46) and Photoshop (47) based on the above concepts. These included physical prototypes and digital wireframes, allowing users to visualise and interact with the proposed interventions.

5.3.1 Medication Info Deck

Pre-packaged medication information leaflets often contain an excess of unnecessary medical jargon. Using fexofenadine as an example for this prototype, the author gathered information from the pre-packaged leaflet, the NICE BNF website (7), and a variety of internet forums to better understand patient concerns.

Fexofenadine, an antihistamine for seasonal illnesses, was chosen as the medication for this design concept. Although commonly prescribed in the community, it is less known than Piriton, making it the perfect candidate for intervention.

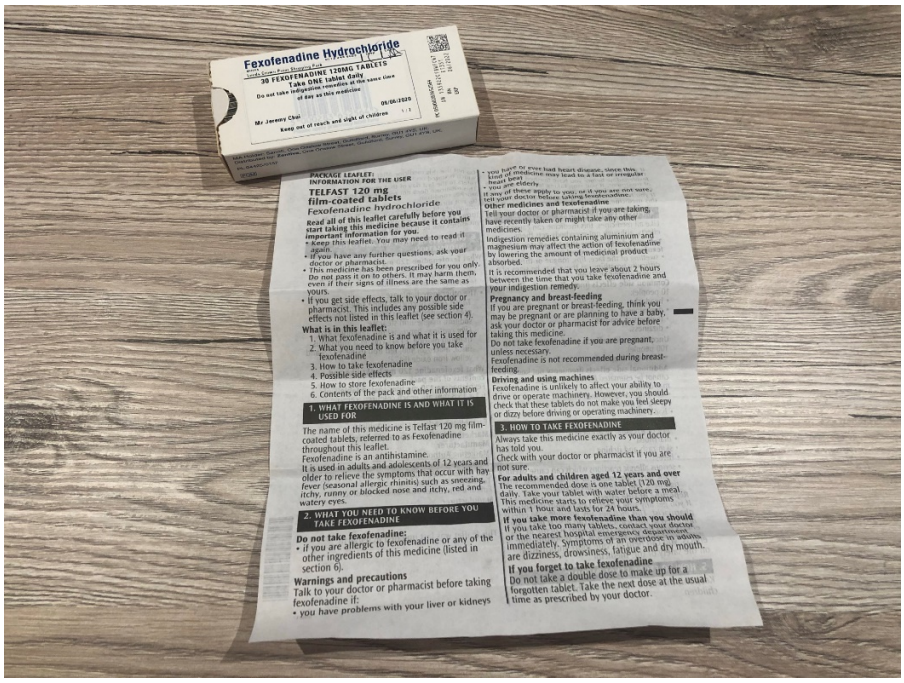

Figure 41. *Example information leaflet from the Fexofenadine pill package*

The author gathered information across various internet forums, including Patient.info, Pharmacy-forum.co.uk and Drugs.com, to better understand users' concerns when taking this medication (48–50, Figure 42).

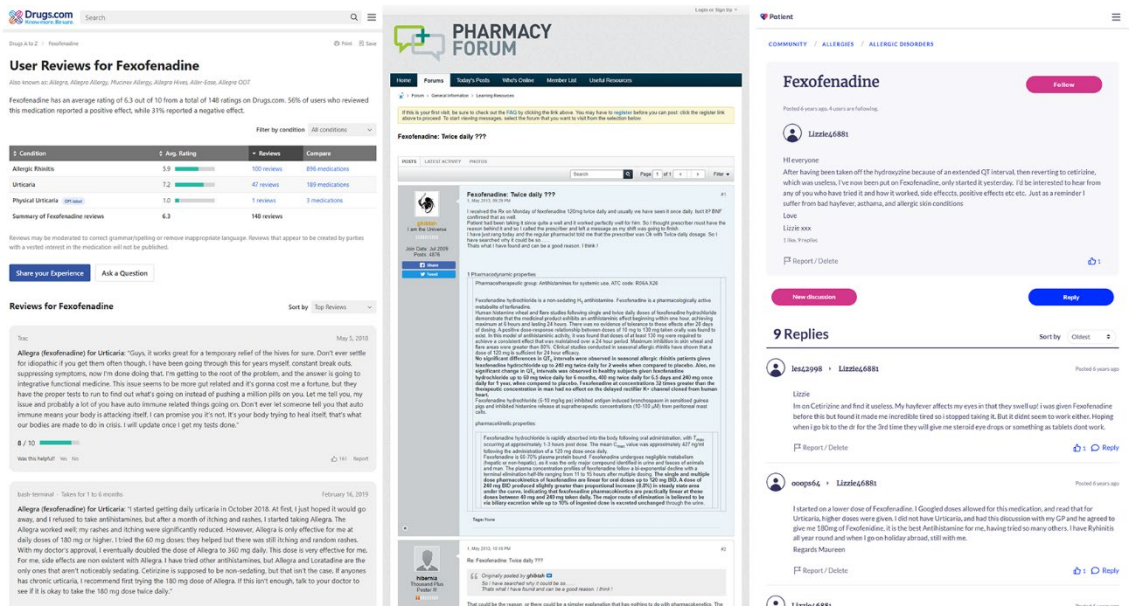

Figure 42. *Forum feedback on fexofenadine* (48–50)

When designing the medication info pack, user concerns were addressed using information from the pre-packaged leaflet and NICE BNF (51). The completed prototype design can be seen in Figure 43.

Figure 43. *Medication Info Pack: Prototype*

5.3.2 Digital Pillbox

Dosette boxes are often given to patients with polypharmacy in the community (Figure 44). Assembled and issued by pharmacists, they help patients and carers simplify their complicated regimens and track medication use.

However, such boxes alone are not a complete solution. Patients can still forget to take their medication and require prompting from alarms. Furthermore, it is often difficult for their family, carers, and primary care providers to track their medication compliance.

Figure 44. *Traditional dosette box* (3)

The pillbox prototype demonstrated where the electronic ink technology would be applied and how a break in an individual pill packet would cause an interruption in the circuit (Figure 45).

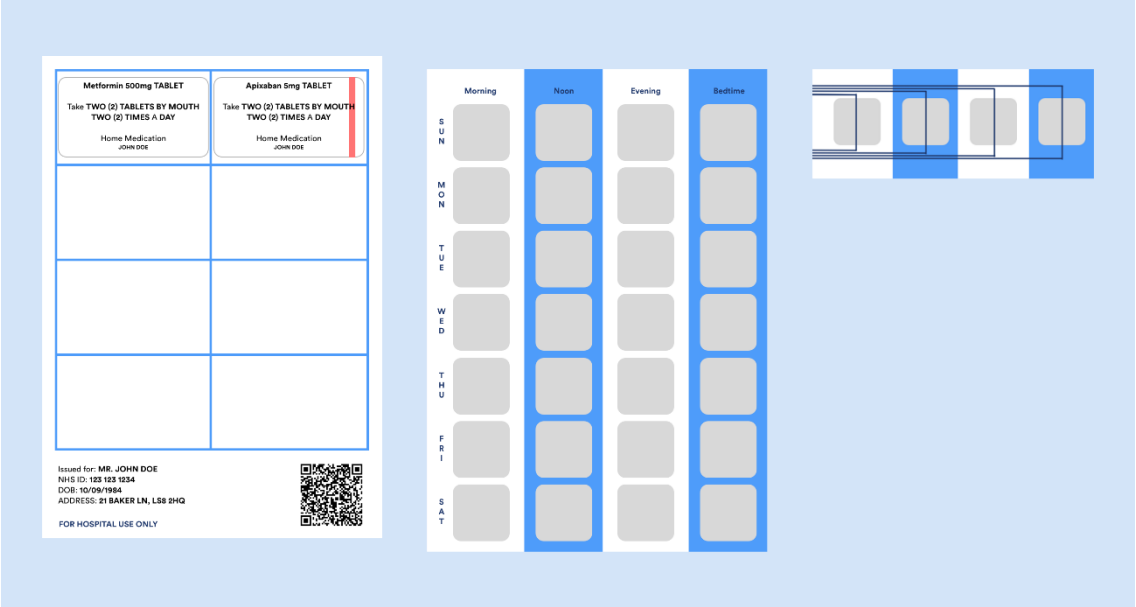

Figure 45. *Redesigned dosette box*

A low-fidelity application wireframe was designed to determine how medication alarms and medication regimens would be tracked and presented in the final application (Figure 46).

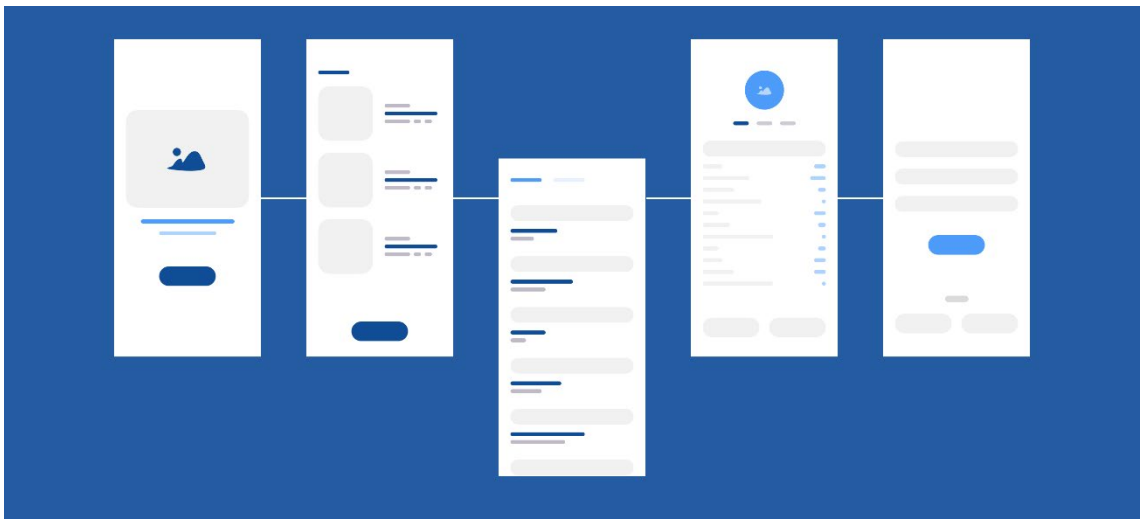

Figure 46. *Digital Pillbox: Companion application wireframe*

5.3.3 Virtual Doctor

Our primary and secondary research showed that patients often felt that they were not receiving personalised care and could not discuss their concerns with a trained professional.

The virtual doctor aims to help individuals who do not require a general practitioner but need assistance reviewing their regular medications. Built from existing guidelines and protocols that medical professionals use to conduct medication reviews, the virtual doctor will be able to review their prescribed regimens routinely and feedback any recommended changes to their general practitioners.

An example of this user journey is the review of simple analgesics, such as paracetamol, and the addition of newly prescribed medication. The application mockup demonstrates interactions between the user and the application, with AI-generated prompts and questions guiding the user through the review process (Figure 47).

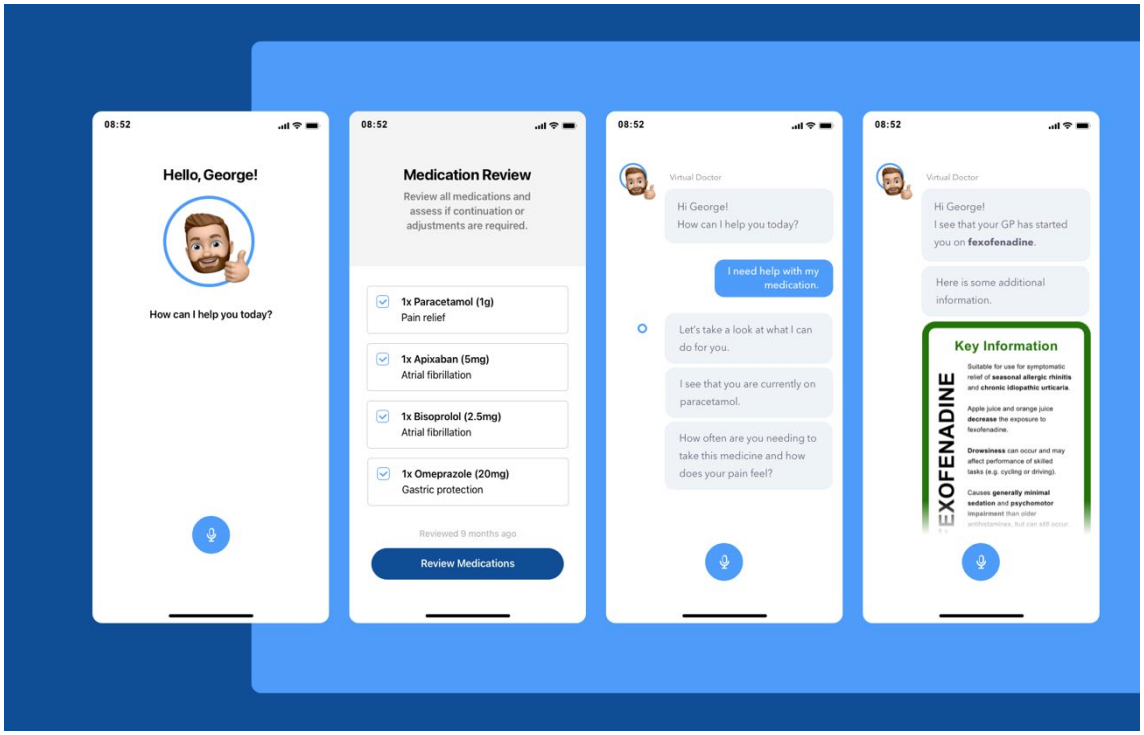

Figure 47. *Virtual Doctor: Application mockup*

Furthermore, medications such as antihypertensives can be adjusted based on pre-existing guidance (Figure 48).

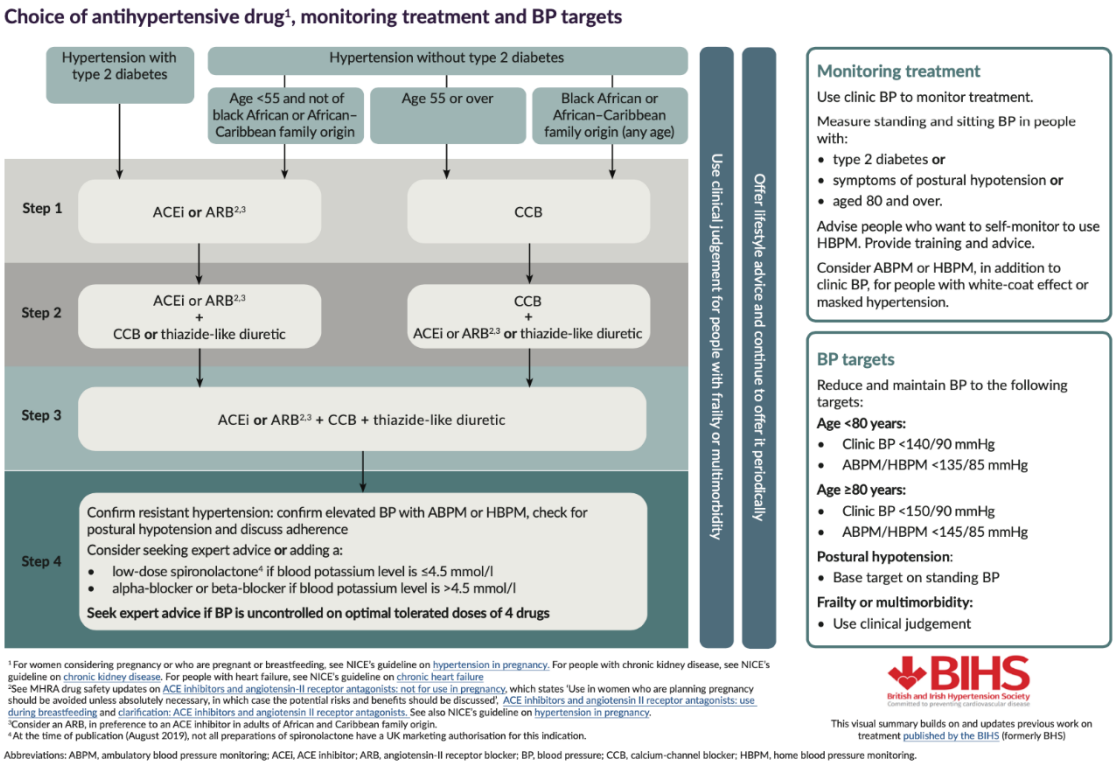

Figure 48. *Virtual Doctor: Hypertension NICE Guideline* (52)

5.4 Co-Design Workshop Feedback

The prototypes were then introduced to participants in a small co-design workshop with six participants. The participants were asked to assess each of these products based on the APEASE criteria. Miro (53), a digital whiteboard, was used as a medium to collate feedback from participants and organise them based on positive and negative experiences.

The **medication info deck** received mixed reviews from participants (Figure 49). The majority of participants felt that the information presented through the redesigned cards

brought additional clarity and addressed their primary concerns when taking their medication. Conversely, a few participants felt that it would be risky to replace existing information leaflets, and the simplified cards would lead to additional confusion.

Figure 49. *Co-Design Workshop: Medication info deck*

The **digital pillbox** received the most interest from participants, with generally positive reviews (Figure 50). Participants were intrigued by the integration of a physical and digital product and understood the benefits of adapting existing dosette boxes digitally to aid familiarisation with existing patients. However, participants were concerned about the costs of developing this product compared to the other proposed design solutions. In addition, partnerships with pharmacies and NHS services would be required to successfully implement this product in the community.

Figure 50. *Co-Design Workshop: Digital pillbox*

Figure 51. *Co-Design Workshop: Virtual doctor*

The **virtual doctor** received the most critiques out of the proposed design concepts (Figure 51). Participants generally felt that a virtual doctor would not address their needs for personalised care and that they lacked confidence in computer algorithms managing their healthcare. One example of ineffective digital assistants a participant mentioned was the NHS 111 online service, an online triage tool designed to provide health information, advice, and supply emergency prescriptions (54). The participant felt that current artificial intelligence advancements limited the virtual doctor process and could not replace a clinician review.

5.5 Proof-of-Concept

Given the positive response and significant interest in the technology behind the **digital pillbox**, the author iterated on this concept further to build a working prototype. Following a rapid prototyping approach, the overall design and physical components were kept minimal to focus on the usability and functionality of the prototype.

Introduced to the MSc cohort during the Helix Design Dash module, an Arduino device was chosen to provide the digital backend technology for this product (55). The open-source nature of the product made it easily customisable and flexible, offering a variety of digital and analogue inputs. Furthermore, its affordability and lightweight nature made it the ideal choice for our project.

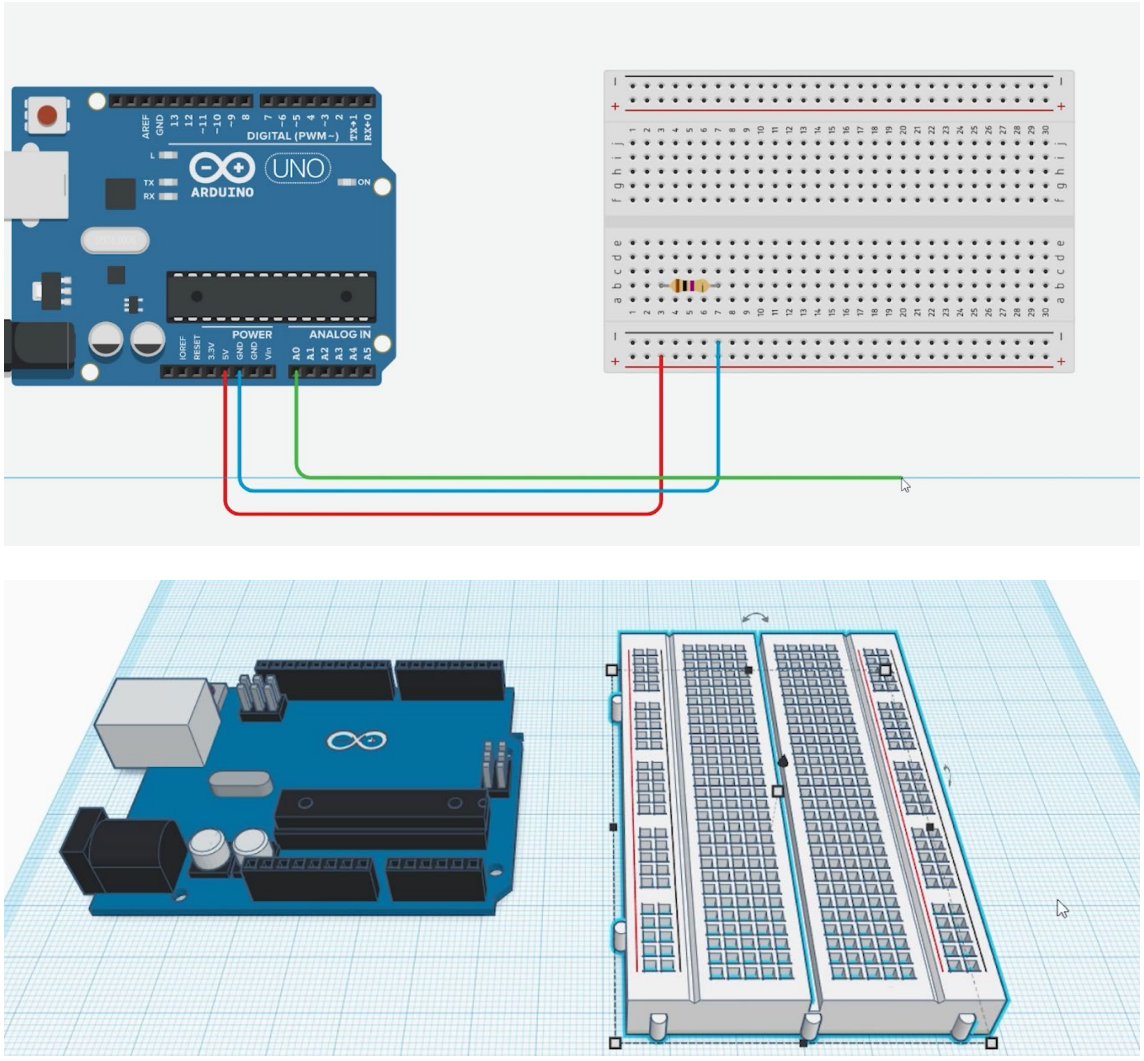

Figure 52. *Tinkercad Arduino circuit design simulator* (56)

Tinkercad (56) was used to simulate the Arduino circuit design before physical assembly (Figure 52). We were able to test out various layouts and capacitors required to establish the technical requirements for our proof-of-concept product. Once satisfied with the circuit design, we built a physical model with an Arduino kit (Figure 53).

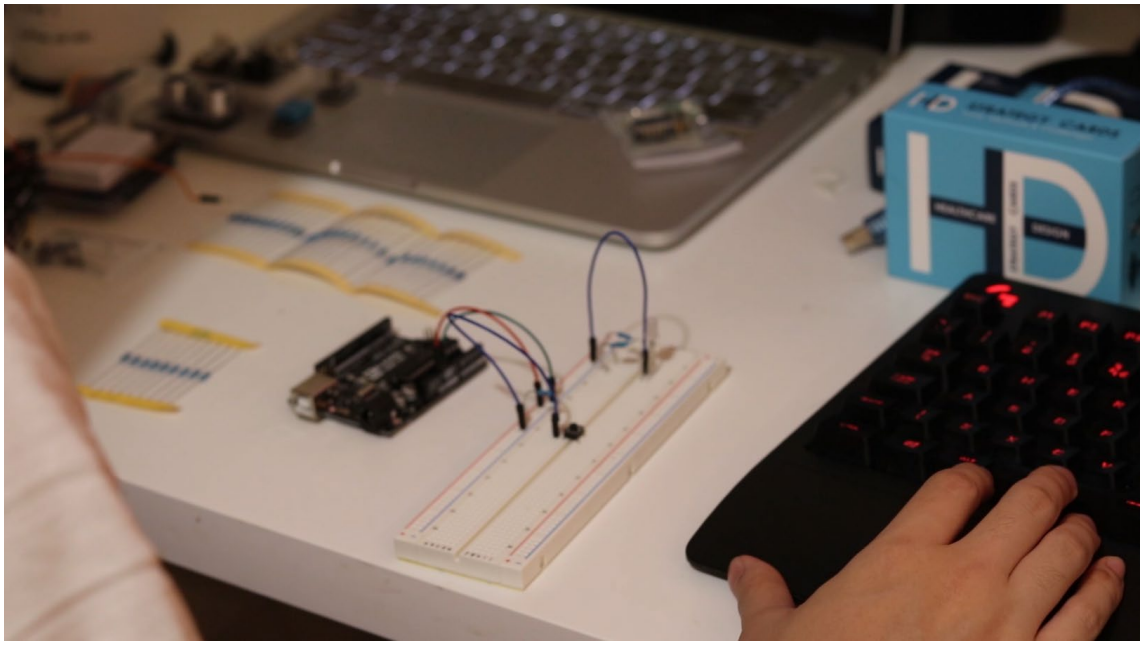

Figure 53. *Digital Pillbox: Building the circuit board*

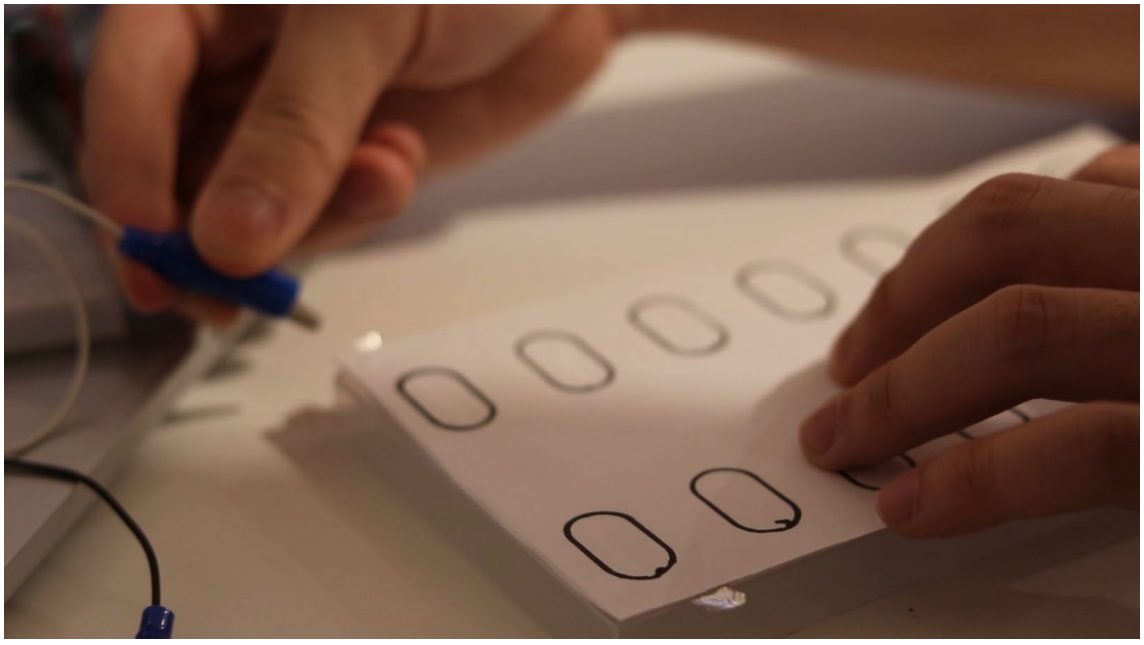

Figure 54*. Digital Pillbox: Attaching leads to the conductive material*

The conductive ink material was simulated using strips of aluminium foil, allowing the author to iterate on multiple designs at a low cost instead of commissioning multiple printouts of conductive ink patterns (Figure 54).

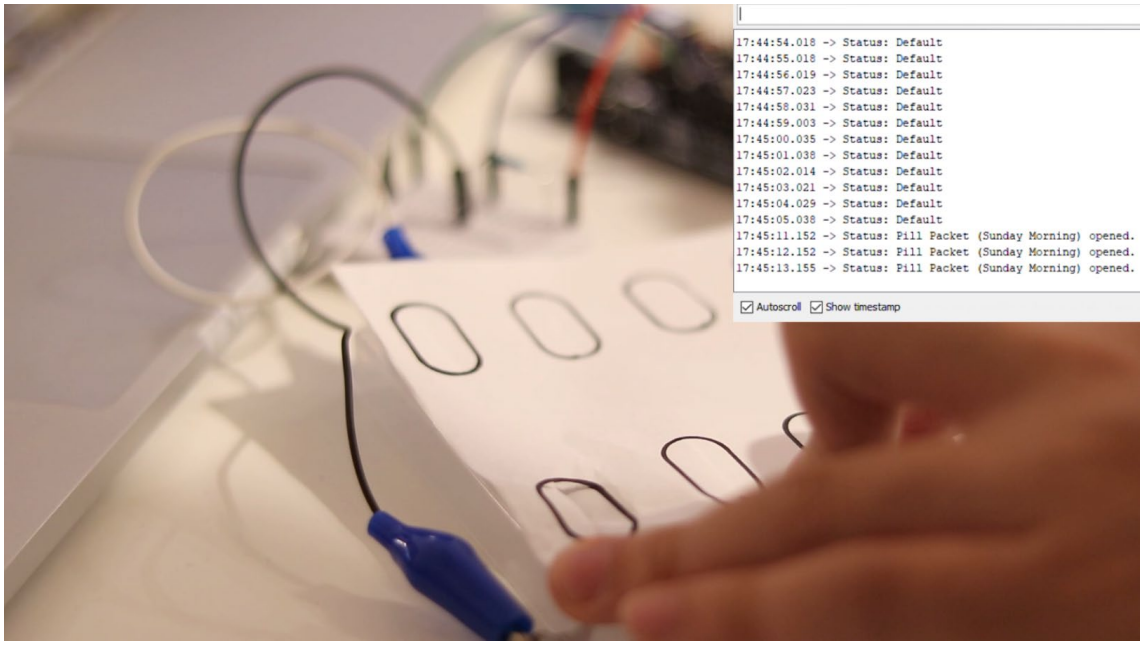

Figure 55. *Digital Pillbox: Testing opening the pillbox*

The Arduino instantly detected any breaks in the conductive material, and a notification was subsequently sent to the connected computer, detailing the exact time and pill package that was opened (Figure 55). The completed physical prototype is shown in Figure 56.

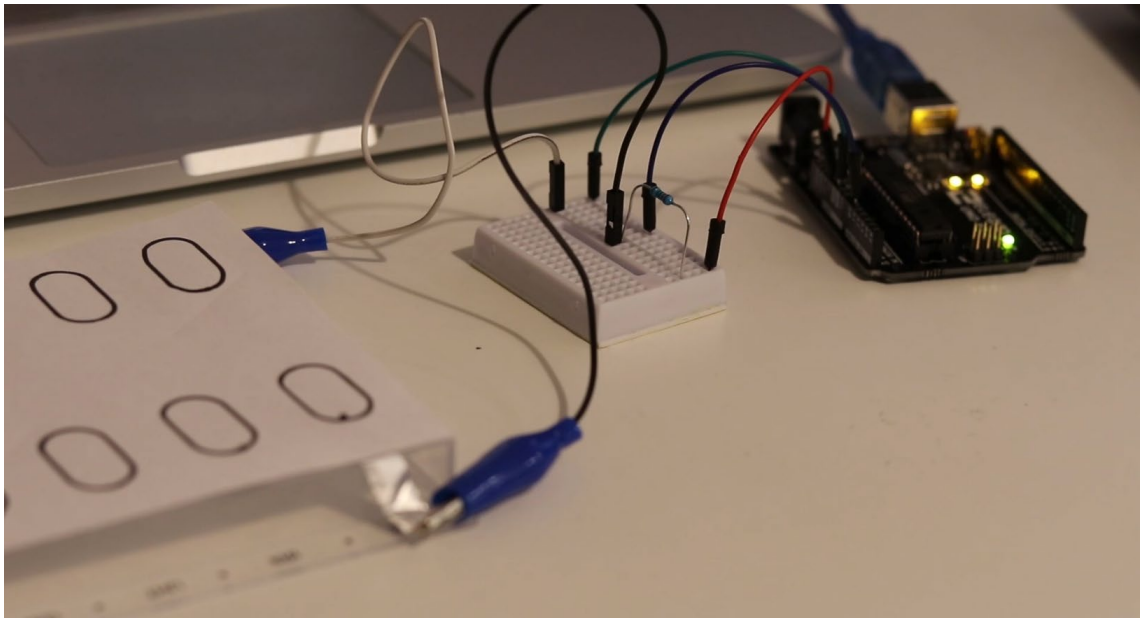

Figure 56. *Digital Pillbox: Completed proof-of-concept prototype*

Finally, high-fidelity mobile application wireframes were created using Sketch (46). These designs were then hosted on Invision (57) to demonstrate an interactive prototype suitable for usability and desirability testing (Figure 57).

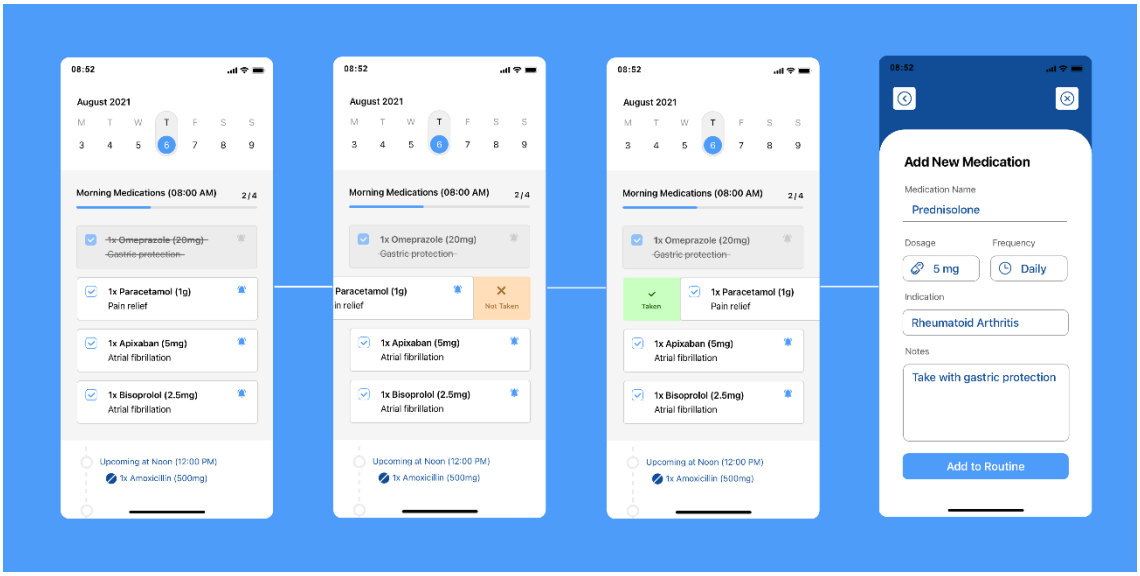

Figure 57. *Digital Pillbox: Mobile application design*

5.6 Proposed Solution

The **digital pillbox** solution, Pillbox Health, was designed to assist patients with chronic illnesses to track their medication usage and monitor their healthcare needs.

Our proposed solution addresses the requirement for medication tracking through its companion application. It builds a personalised user profile based on each individual's medication regimen to tailor their reminders and alarms to their existing routines (Figure 61).

This solution was designed to be implemented in three parts. First, existing dosette boxes were redesigned to incorporate conductive ink packaging (Figure 58).

Figure 58. *Pillbox Health: Dosette box packaging*

Second, a reusable Arduino-based electronic device was designed to send information from dosette boxes to smartphone devices (Figure 59).

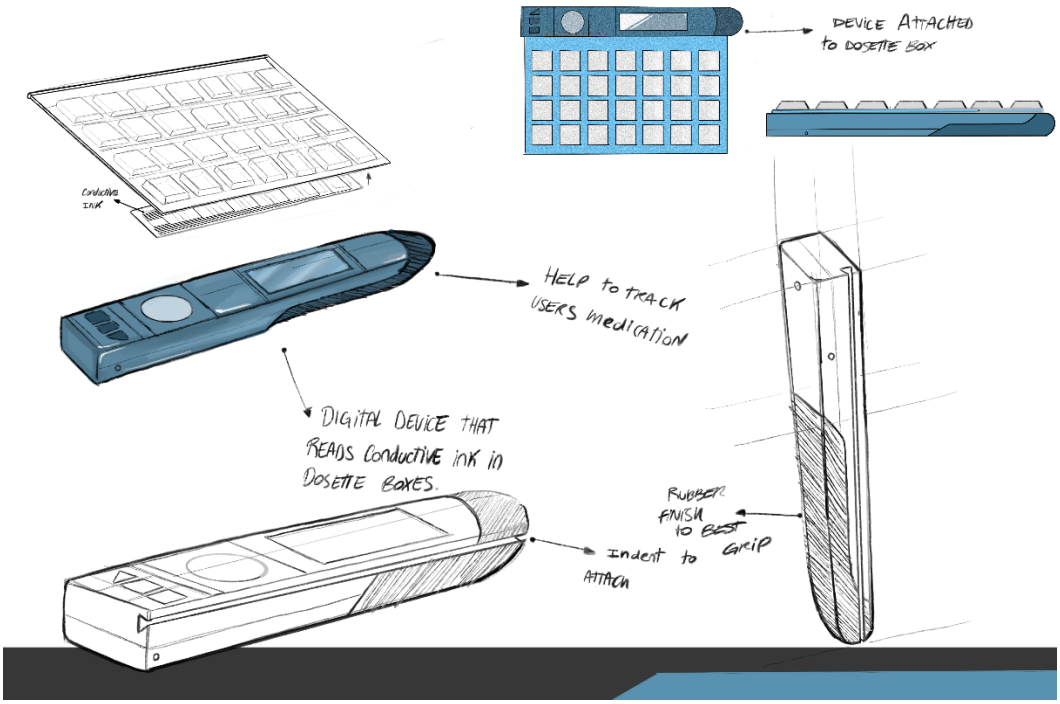

Figure 59. *Pillbox Health: Digital device*

Finally, a companion mobile application was introduced to collate all the medication tracking information and set personalised alarms based on a user's medication regimen (Figure 57).

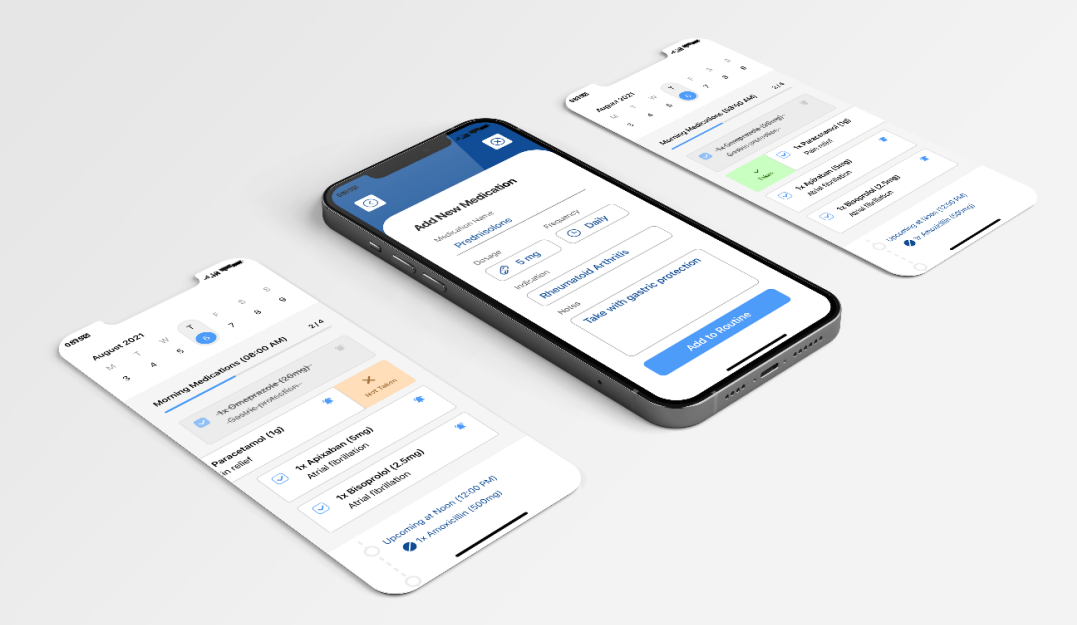

Figure 60. *Pillbox Health: Companion application*

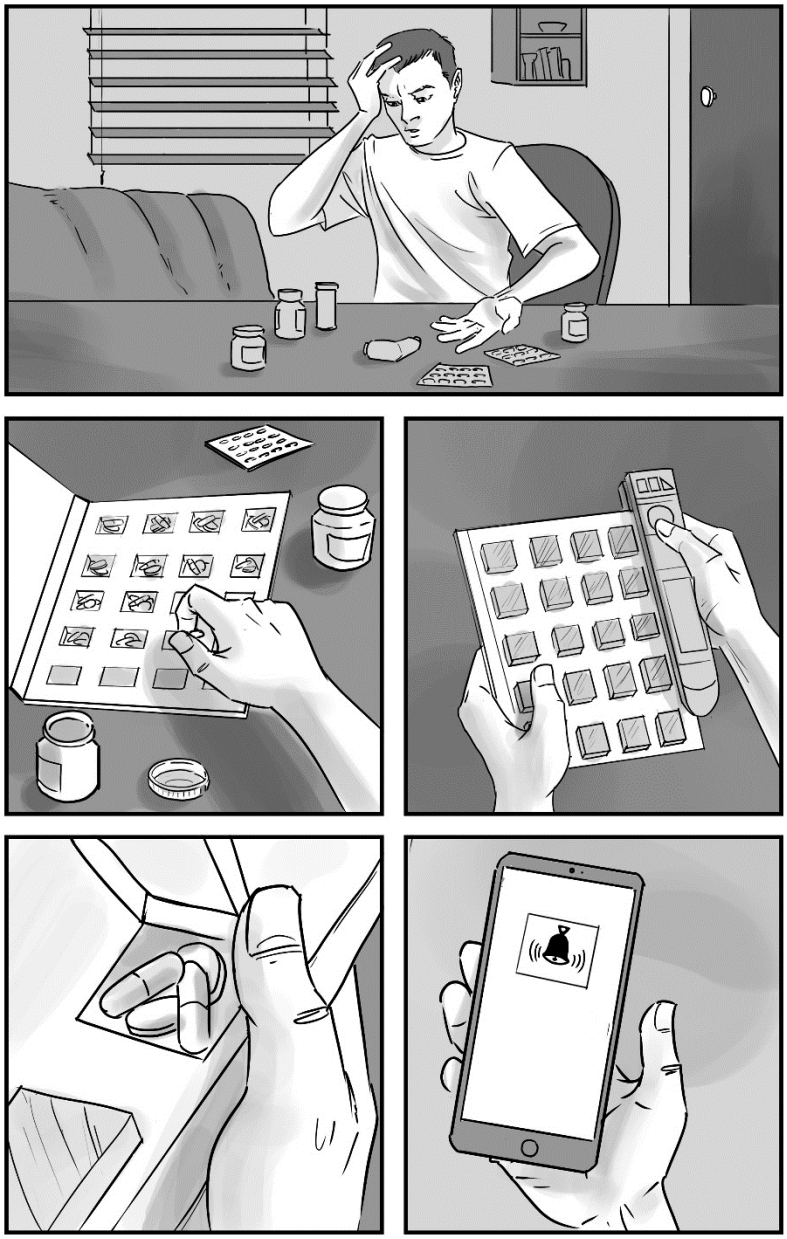

Figure 61. *Pillbox Health: Storyboard*

Future iterations of this solution could include automated medication reviews and a digitised version of the medication info pack, combining the best aspects of each of our design concepts.

6 Deliver

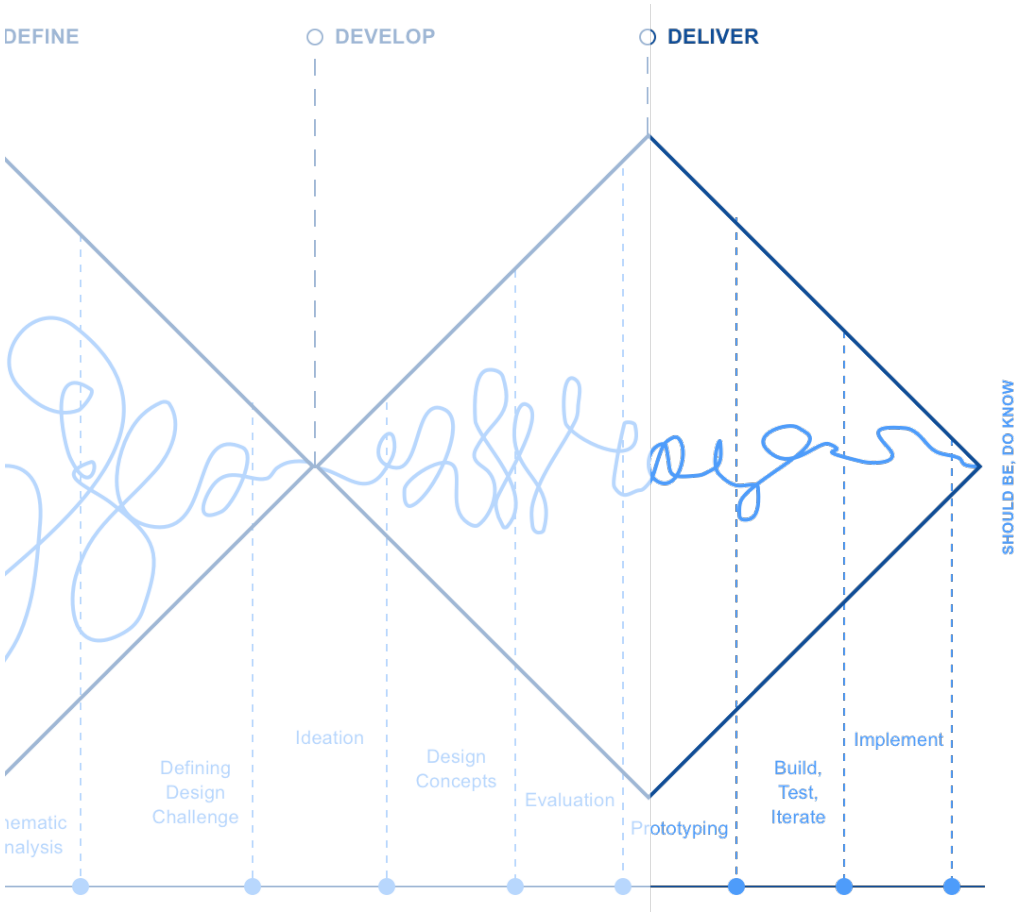

Figure 62. *Deliver Process*

6.1 Approach

This section aims to build, test, and iterate on the previously identified solution. The author evaluates the proposed solution through desirability and usability testing and presents a product roadmap and delivery strategy for implementing the final solution within a healthcare environment.

6.2 Build, Test, Iterate

Design thinking prioritises a user-centric approach to problem solving and innovation. We aim to refine and improve our final product through continuous feedback from users and stakeholders by utilising an iterative process.

After identifying a proposed solution and developing a functional prototype, the author evaluated our proposed solution further through usability and desirability testing.

6.2.1 Product Desirability

Desirability can be defined as how users can be driven towards taking action through design (58). Desirability studies play a vital role in understanding users' attitudes and opinions towards a product.

High-fidelity mockups of the proposed solution were created and described in detail on an online landing page (Figure 63). By presenting this information to the public early in the development and delivery process, we can identify our value proposition and validate our idea before introducing it to the market for public adoption.

Call-to-action buttons were placed throughout the website to encourage visitors to sign up for early access (Figure 64). Conversions from the call-to-action button were measured and allowed us to quantify the amount of interest potential customers had in adopting our product. This method of desirability testing also allowed us to gain deeper insights into our future customers' intentions and demands.

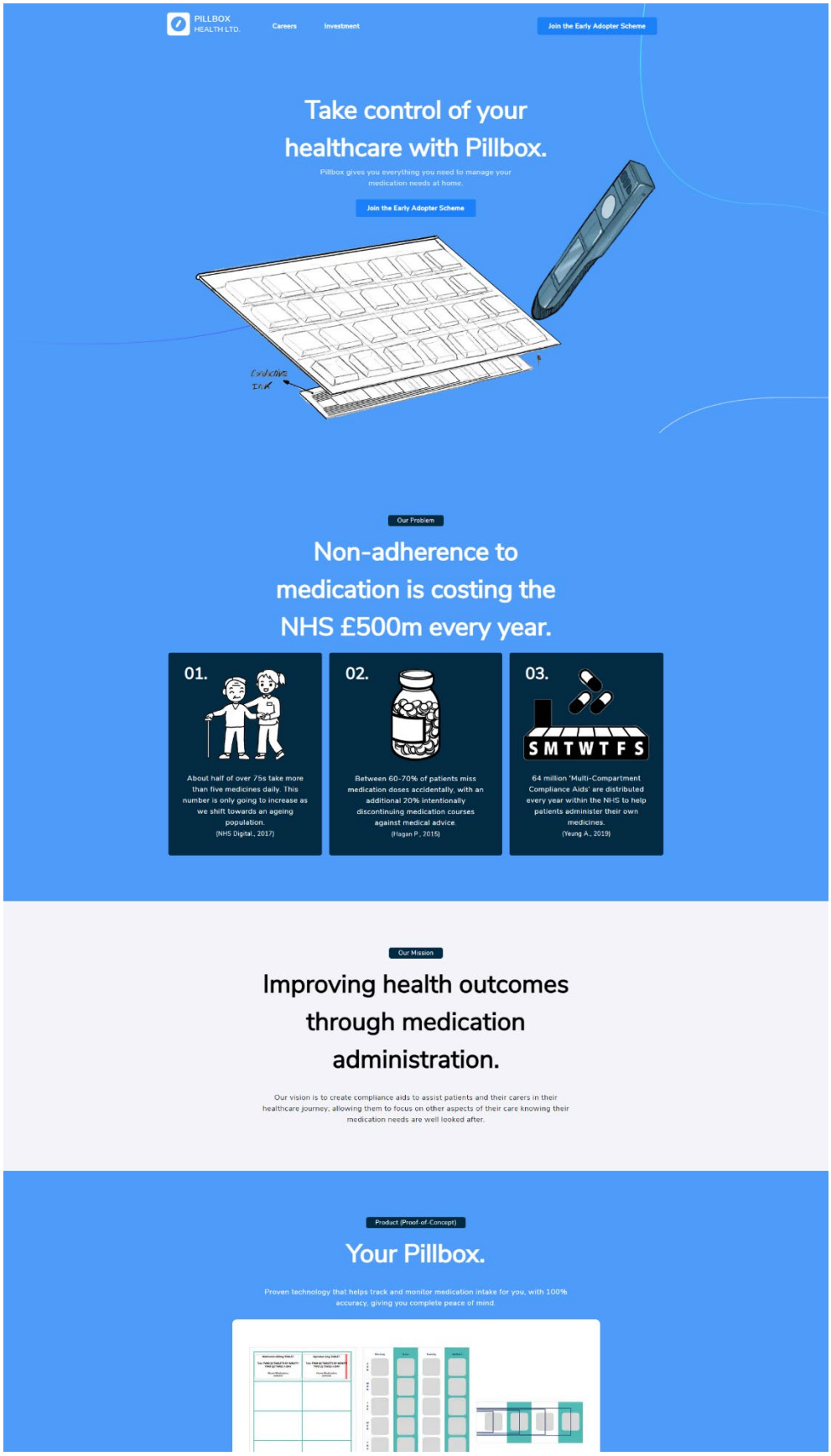

Figure 63. *Pillbox Health: Landing page design*

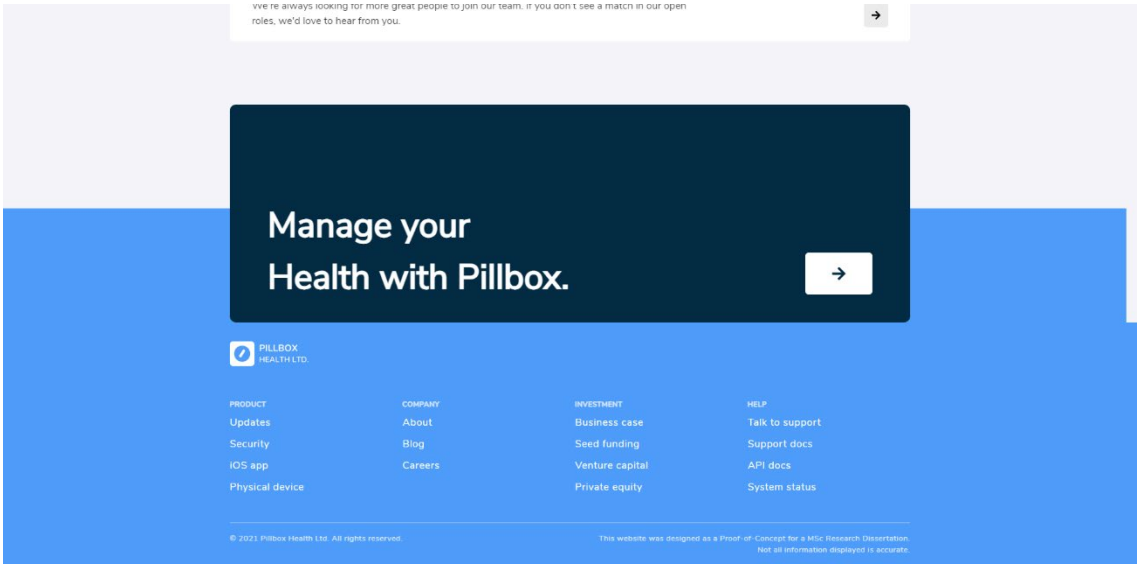

Figure 64. *Pillbox Health: Call-to-action button*

Website feedback from users confirmed that the market attractiveness is well justified and 'piques interest' in visitors to the page. Users also felt that the goals and timelines of this project were 'well articulated' and presented in a 'clean and clear structure'.

6.2.2 Usability Workshops

The Nielsen Norman Group, a UX design firm, defines usability as an attribute that assesses how easy user interfaces are to use (58). This attribute can be broken down further into five components:

1. The ease with which users can complete tasks when they are first introduced to the product
2. The speed users can complete tasks after they have become familiar with the product
3. How easy users can re-familiarise themselves with the product after a period of not using it

4. The number of mistakes users make with the product and how quickly they can recover from them
5. The product's user-friendliness

To assess the usability of our proposed solution, the author organised product demo workshops with a small group of participants. The workshops introduced the tasks that had to be performed by the participants, such as tracking medication use and setting reminder alarms. Participants were then offered the prototype as a tool to assist them in their actions. The product's usability was then recorded and measured across the previously listed five domains (Figure 65).

Figure 65. *Pillbox Health: Usability workshop*

Our participants found that the proposed digital pillbox concept was similar to existing dosette box designs. They were able to understand the principles of the digital

prototype and rapidly adopt this new technology into their existing medication routines. However, one of the participants found the digital companion application to be less straightforward to operate. They experienced difficulties in entering the medication information into the app and inputting their medication regimens correctly. Future improvements could include automatically pulling prescription information from GP practices and syncing them with the companion application.

6.3 Business Model

The author developed a business model for our proposed solution by utilising the business model canvas (50) and skills taught during the MSc programme. This tool provided a visualisation of multiple components required to implement our product, including key performance metrics, value proposition, cost structures, and potential revenue streams (Figure 66).

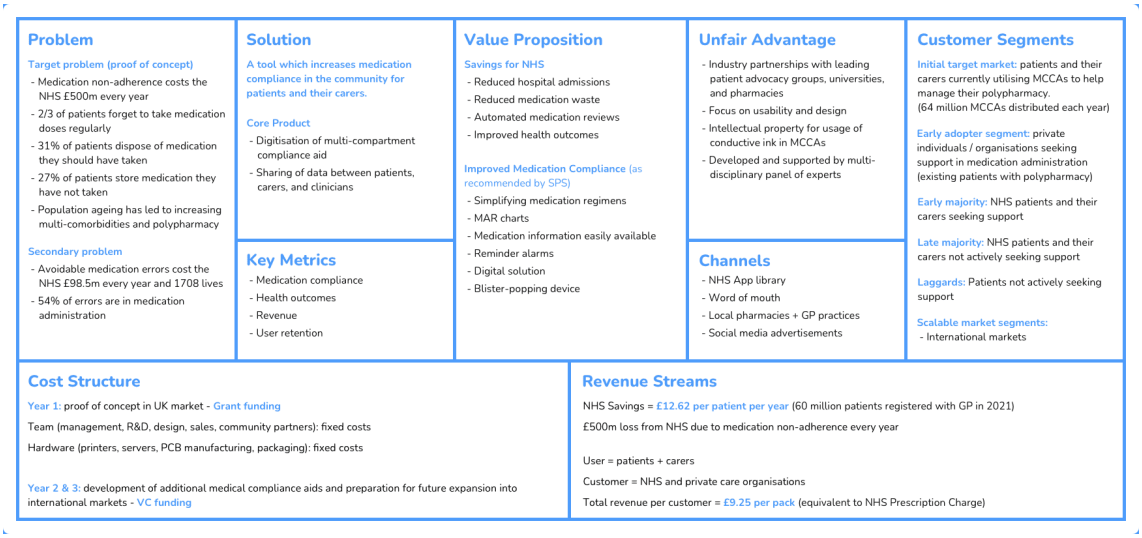

Figure 66. *Pillbox Health: Business model*

Key metrics, such as health outcomes, were identified to recognise the product's sustainability and effectiveness. These metrics would include monitoring peak flow

results in asthmatics and blood sugar levels in people with diabetes. Positive findings that correlated with improved medication compliance would indicate product usefulness.

Based on Everett Rogers' diffusion of innovation, target customer segments were divided into five categories: innovators, early adopters, early majority, late majority, and laggards (59). Innovators were identified as patients and their carers currently utilising medication aids to help manage their polypharmacy. The goal is to provide innovators and early adopters with a product they are already familiar with whilst introducing innovative features to support their medication compliance. As we further refine our product and deliver it to the larger population, we intend to involve patients and carers from private and NHS organisations as part of the early and late majority, eventually scaling into international markets.

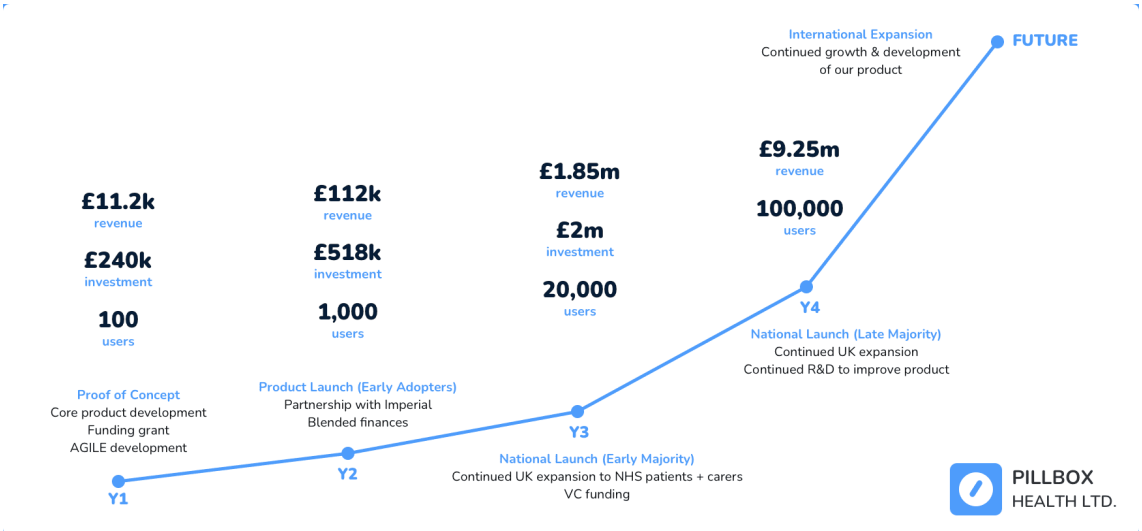

Figure 67. *Pillbox Health: Product milestones*

Product milestones were also illustrated as part of our proposed business plan (Figure 67). The roadmap began with a proof-of-concept model delivered to 100 users, funded

by research and NHS grants, before scaling to a profit-generating model alongside continued UK expansion.

Running costs were estimated based on fixed costs from the team (management, R&D, design, sales, community partners) and hardware (printers, servers, PCB manufacturing, packaging) components.

The proposed cost of each digital pillbox is £9.35, equivalent to the NHS Prescription Charge (60), whilst reducing overall health costs by £12.62 per patient per year (based on a population of 60 million patients registered with GPs in 2021 and a £500m loss from NHS due to medication non-adherence).

6.4 APEASE Criteria

Lastly, the proposed solution of a digital pillbox was evaluated using the APEASE criteria from our literature review.

Affordability

The proposed price-point for each digital pillbox is equivalent to existing NHS prescriptions, designed to be affordable to the general population already utilising medication compliance aids. Given the estimated health outcome cost savings from the introduction of improved medication tracking, this price may be subsidised further with sustained partnerships together with NHS and pharmaceutical services.

Practicability

Implementation of the digital pillbox will be dependent on the adoption of redesigned dosette boxes (with electronic ink strips) by pharmaceutical services. Our proof-of-

concept model has shown that these devices can be implemented and utilised as intended. The low-cost solution of integrating electronic ink should aid in the adoption of this technology.

Additionally, a standalone version of the companion app will also provide digital medication tracking without the automated synchronisation with the physical dosette boxes.

Effectiveness & Cost-effectiveness

Multiple studies during our literature review have shown that the use of digital medication compliance aids can improve medication compliance (8,9,41). Furthermore, based on estimated cost-savings of £12.62 per patient per year from improved health outcomes due to medication adherence, this intervention will also prove cost-effective following community implementation.

Acceptability

Preliminary feedback from user interviews, workshops, and online responses demonstrated a keen interest and desirability for this product amongst patients and their carers. However, there is limited information regarding acceptability among healthcare professionals, and further appraisal is required. One such method would be applying to healthcare grants and funding sources to open a discussion with key healthcare stakeholders and evaluate their interest and acceptability of this product.

Side-effects & Safety

Because this innovation is based on existing, proven solutions such as medication compliance aids and digital reminders, there is a low risk of unforeseen adverse outcomes to this solution. This solution's potential side-effects could lead to patients'

reliance on digital technology to track medication usage and reduced awareness of their medications.

Equity

We feel that this intervention is fair to all members of society. Patients who already utilise dosette boxes as medication compliance aids will find the digital pillbox familiar and easy to adopt. Patients and carers unfamiliar with dosette boxes or mobile applications will be presented with user-friendly walkthroughs via the companion application, ensuring that all users have a smooth and positive onboarding process.

7 Discussion

7.1 Summary

This dissertation explored the ways design thinking can help understand medication compliance issues and generate insights to improve health outcomes.

Our literature review validated the importance of good medication compliance to promote better health outcomes. In addition to significant cost savings from medication wastage, multiple studies have also demonstrated improvements to patient health in conditions such as asthma, stroke and heart disease.

Adopting a design thinking approach, we approached this challenge by developing a deep understanding of our target audience and their needs. Through a combination of primary and secondary research, we sought to understand the shared behaviours and challenges that patients with poor compliance face. In doing so, we identified recurring themes, such as forgetfulness and a lack of personalised care, as barriers to good adherence.

We found the APEASE model for evaluating innovations to be particularly valuable when investigating methods to support patients with medication compliance issues, ranging from pharmacy-led medication reviews to electronic medication tracking devices. This model provided the author with a framework for adjusting and prioritising different aspects of the product development cycle to deliver a practical and effective solution.

Our findings led us to the design and development of a digital pillbox, Pillbox Health (61). The product aimed to address issues with medication compliance through electronic tracking and alerts whilst presenting a familiar experience to individuals already using medication compliance aids.

Applying an agile approach to product development was key in completing our two-year research during the MSc programme. We built a proof-of-concept prototype of our device, conducting ongoing iterative changes and refinements through co-design workshops and usability tests. A product roadmap and business model were also created to help identify future product development and market adoption requirements.

7.2 Strengths

The systematic review conducted as part of this research was comprehensive and context-specific. Our literature review not only validated our design challenge but also led to the identification of critical insights such as stakeholders, shared behaviours, and evaluation tools.

The adoption of an agile methodology during our research process allowed us to engage with our end-users throughout our products' design and development process. This process led to continuous refinement and improvement of our technology with meaningful end-user involvement and participation.

Furthermore, our design thinking approach helped focus on our target audience's behaviours and needs, allowing us to develop an effective solution that addresses their primary concerns. This strategy, along with the double diamond framework, guided the author through the application of divergent and convergent thinking across the study.

7.3 Limitations

There is currently limited evidence surrounding the use of digital medication compliance aids in improving medication adherence. Although our secondary research found multiple examples of such devices being used in a community setting, these technologies are often applied to specific healthcare conditions, such as stroke or HIV. Furthermore, many of these studies did not fully account for co-existing co-morbidities and other healthcare factors, such as reliance on care workers, that patients may be experiencing.

Unfortunately, most of this research occurred during multiple COVID-19 lockdowns, resulting in limited opportunities for hands-on product demonstrations and design workshops. Although digital meetings and small-group activities substituted these, the number of participants in this study were restricted as a result. This research sought to provide a comprehensive and detailed evaluation of the use of design thinking in developing healthcare products to aid medication compliance. However, the limited number of participants in this study may have introduced bias, and a larger sample should, therefore, be recommended in future research.

Due to restrictions associated with the COVID-19 lockdown, university design labs and resources, such as 3D printing, were only available through third parties or remote services. This additional barrier to access new technologies may have limited the scope of what was achievable during this research project, such as the potential for 3D printed dosette boxes with custom circuit boards.

7.4 Future Research

This project began with the identification of a healthcare challenge faced in the community: medication non-compliance.

During this research, the author identified a number of opportunity areas for potential design solutions towards this problem. Although the digital pillbox concept was chosen as the proposed solution for this dissertation, there remain numerous opportunity areas that could be addressed in future research. A group brainstorming session with a multi-disciplinary team may also combine new concepts and challenges not identified during this study.

This study has demonstrated the use of online meetings as a valid and reliable data collection method. Furthermore, the use of an online webpage in assessing the desirability of our product provided us with essential feedback. These alternative methods, as opposed to face-to-face interviews, should also be considered when evaluating upcoming products.

Finally, as recommended previously, a more significant number of participants would be beneficial in reducing bias when interpreting feedback in future studies.

7.5 Conclusion

This dissertation addressed the main objectives it set out to achieve. Although faced with a few limitations, the author adopted a design thinking methodology to tackle a healthcare environment challenge. This human-centred approach helped build a deep understanding of the target audiences' challenges and needs, resulting in the development of a user-friendly and effective solution.

The digital pillbox solution, Pillbox Health, is by no means a finished product. Although preliminary usability and desirability tests yielded favourable feedback, there remains scope for further testing and refinement of this technology.

The author hopes that this study's insights and results will prompt future research and development in this area and promote the use of design thinking in more healthcare challenges in the future.

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Appendices

Appendix A: Primary Research User Survey Questions

1→ Do you have a long-term health condition which you take medication for?

- Y Yes
- N No

OK ✓

2→ How many medications do you regularly take?

0 1 2 3 4 5 6 7 8 9 10

OK ✓

3→ How frequently do you need to take your medication?

If taking multiple types of medication, base your answer on the medication you take the most often.

- A Weekly
- B Daily
- C Twice a day
- D Three times a day
- E Four times a day
- F Other

4→ Have you ever discontinued a course of medication before it was meant to finish?

- Y Yes
- N No

OK ✓

5 → Have you ever missed a dose of medication because you forgot?

Y Yes

N No

OK ✓

6 → Have you ever discontinued a medication because you disliked the side effects?

Y Yes

N No

OK ✓

7 → Have you ever discontinued a medication course because you were feeling better?

Y Yes

N No

OK ✓

8 → What do you do with medication that you did not end up using?

Choose as many as you like

A Return to provider

B Store at home

C Dispose the medication

D Give to other people

E Other

9 → What do you think would help you take your medication regularly?

Or methods that you currently use to help you with your medication regimens.

Type your answer here...

Shift ⇧ + Enter ↵ to make a line break

Submit

Appendix B: Primary Research User Interview Questions

Open General (warming people up)

1. Age bracket
2. Job
3. Interests/ hobbies
4. Condition and what take medication for
5. Type of medication taken (tablets, self-inject, liquids, PICC line, numbers of meds)
6. How do you currently manage your medications at home and where do you store them?
7. (Do you get help to manage your medications/ carers)

Go Deep (understand person's hopes, fears, ambitions/ motivations, frustrations, interactions)

@home

1. Describe your medication routine and what helps you to remember and organise your meds
2. What might cause you to forget your medications? Do you get reminders?
3. Describe your ideal medication storage method?
4. What kind of improvements would you like to see?

@ hospital

5. Could you describe your last in-patient hospital experience, especially in terms of how your medication was administered and your awareness of the ability for you to self-medicate?
6. What is your experience of the self-medication process in terms of initial assessment and continued support with this throughout your stay?
7. How are you and/ or your condition affected by the medication routine in hospitals? What changes would you like to see? (timings, routine changes, control, dose check/ changes, adding new medications)

8. How are you affected by any changes made to your medications whilst in hospital?

9. Would you consider self-administering your medications when in hospital? What would prevent/ encourage you to do this?

10. What are your expectations of nurses during an in-patient stay and their role and responsibility to administer medication?

11. What are your preferences regarding how medications are given in an in-patient hospital environment?

@returning home after in-patient stay

12. What is your experience of returning home after an in-patient stay and how does this affect your medication routine and confidence?

Topics

// Storage of medications + access

// Access to prescriptions - can patients see what medications they are currently taking?

// Documentation of medication administration

// Adverse effects of medications

// Changes to medications

// Medication errors

// Nursing medication errors - past experiences

// Timing errors

// Identification of patients suitable for self administration
(How to start the assessment process? How do they know about this process?)

// How do you take it normally at home?
(Make it familiar to the patient while in hospital setting)

// Sustainability
(How do you maintain the same / similar process during hospital stay + after hospital)

// Variability of operability for patients for self administration

// Safety & hygiene through self-administration of medication

Appendix C: Ethical Approval

CHUI, Jeremy (LONDON NORTH WEST UNIVERSITY HEALTHCARE NHS TRUST)
Sun 18/07/2021 19:33
To: r.nicholson@imperial.ac.uk

Hi Ruth,

I am a Healthcare & Design MSc student at Imperial College London and work as a doctor in North West London.

I am writing to clarify the requirements for approval for my study.

My study will take place in two parts:

- Firstly, as a Service Evaluation of current systems and policies relating to the self-administration of medication
  - Information will be collected through a literature review, online surveys on social media, and user interviews
  - No implementation / proposed interventions will take place
  - Designed to understand the current state of "Self Administration of Medicine" in the community
- Secondly, as a local Audit (+ Quality Improvement Project) in the recording of self-administration of medications
  - Designed based on set standards identified in the service evaluation phase
  - No implementation / proposed interventions will take place during the initial audit - but changes to current practices may be proposed for reaudit depending on results as a Quality Improvement Project
  - Focus on the documentation by clinicians on patient care through review of medical documentation
  - Approval via local Trust QI procedures + clinical governance

My understanding is that neither of these will require ethical approval via R&D office / NHS REC. However, wanted to be certain regarding the potential development of a Quality Improvement Project from this study.

Thank you for your time.

Regards,

Jeremy

Dr Jeremy Tsz Kwan Chui
ACCS ST1 Emergency Medicine Doctor
London North West University Healthcare NHS Trust

NM

Nicholson, Ruth M <r.nicholson@imperial.ac.uk>
Mon 19/07/2021 08:03
To: CHUI, Jeremy (LONDON NORTH WEST UNIVERSITY HEALTHCARE NHS TRUST)

HI Jeremy,

You a correct- service evaluation and subsequent service improvement projects do not require ethical approval.

Many thanks

Ruth Nicholson
Head of Research Governance and Integrity
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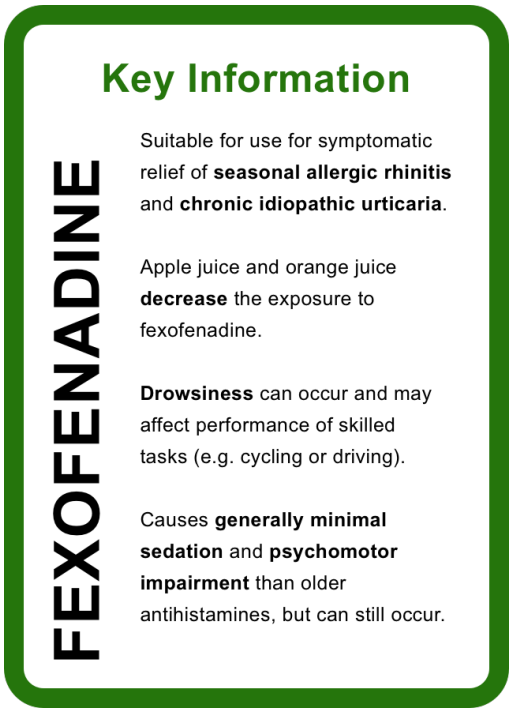
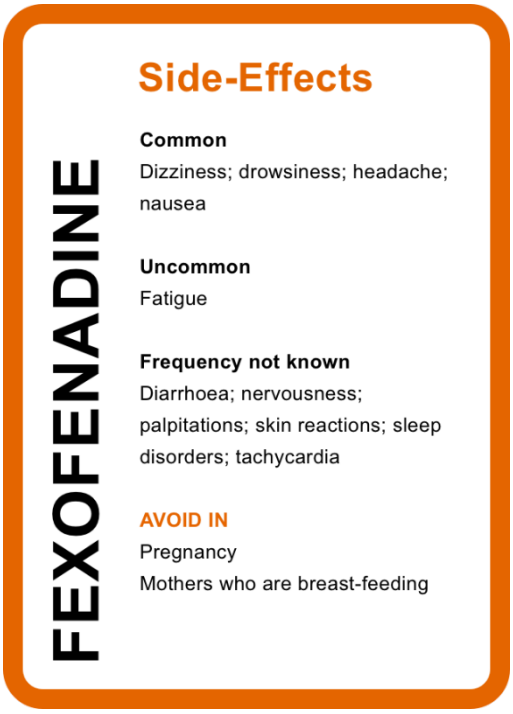
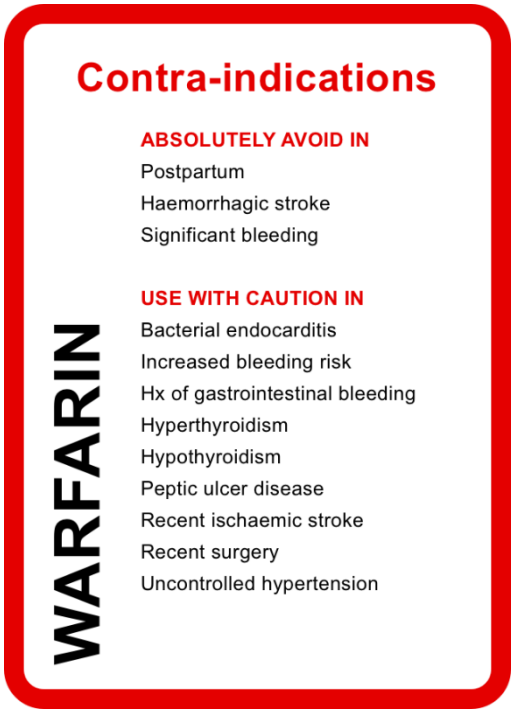
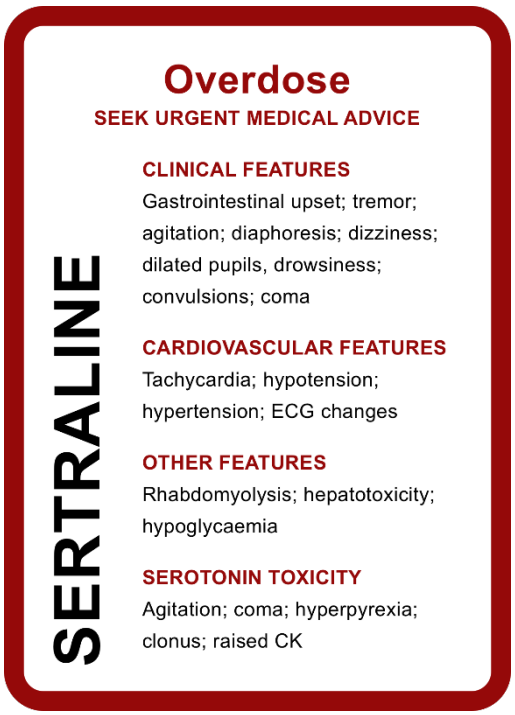
Level 2, Medical School Building
Norfolk Place,
London W2 1PG
020759 41862
r.nicholson@imperial.ac.uk
https://www.imperial.ac.uk/joint-research-compliance-office/

Appendix D: Sample Medication Info Deck Cards

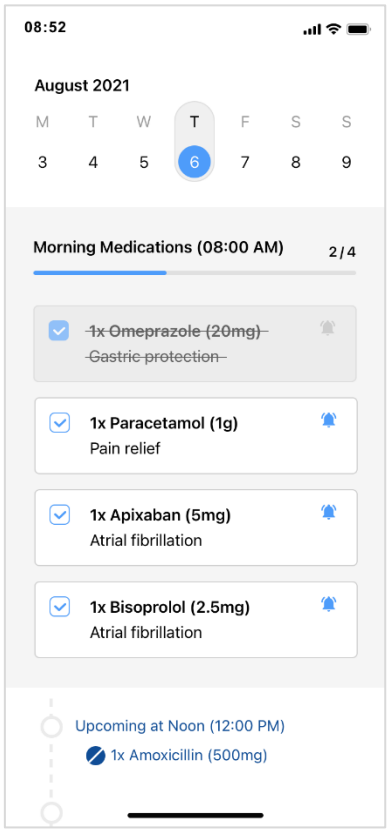


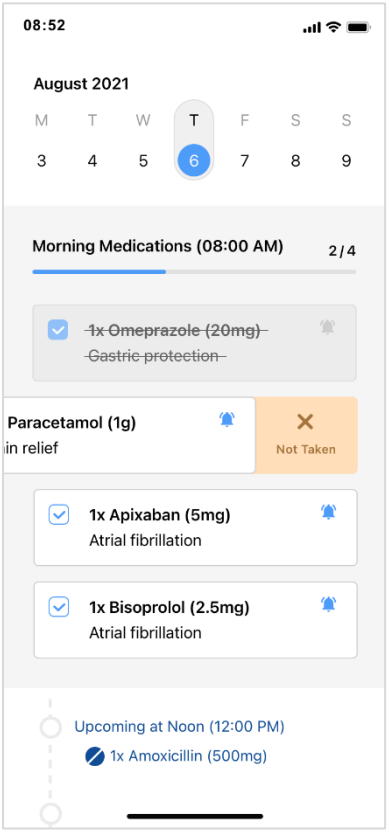


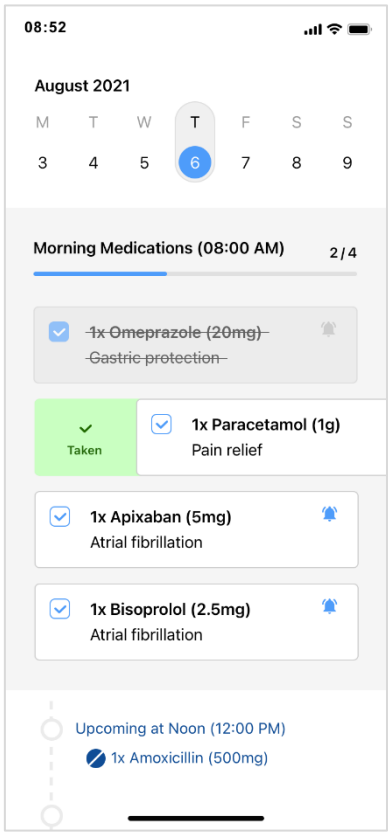


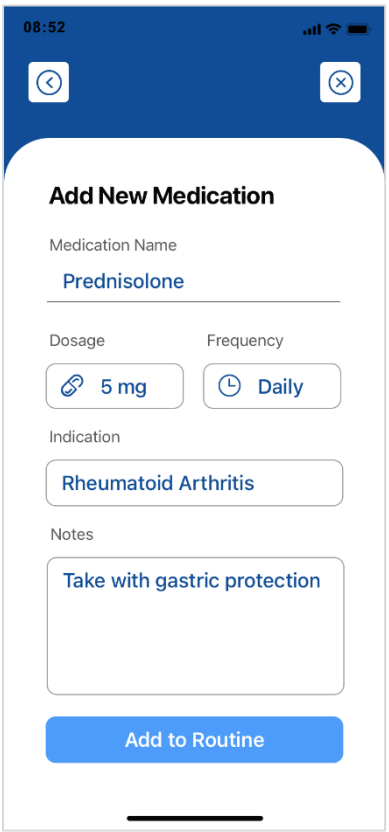


Appendix E: Digital Pillbox App



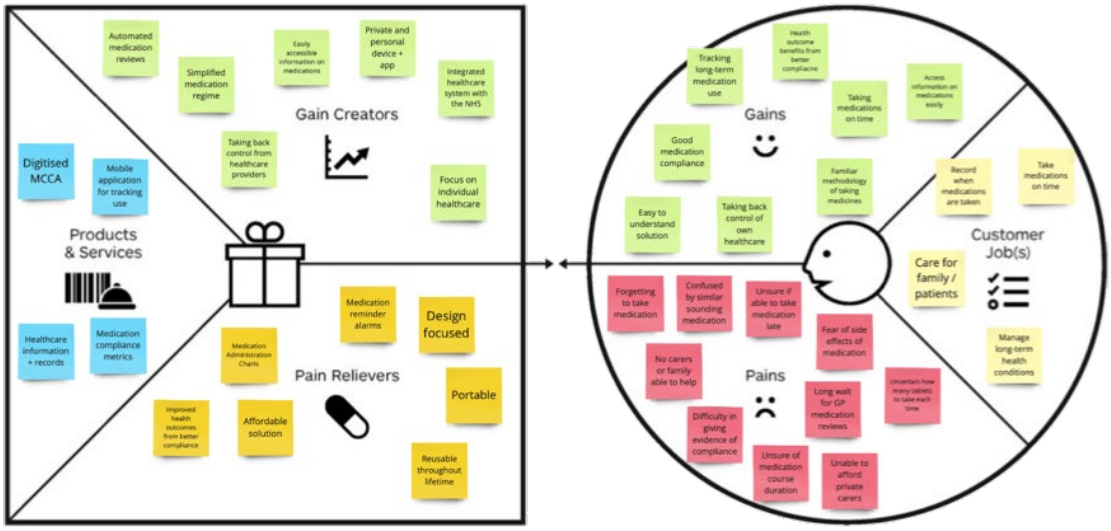




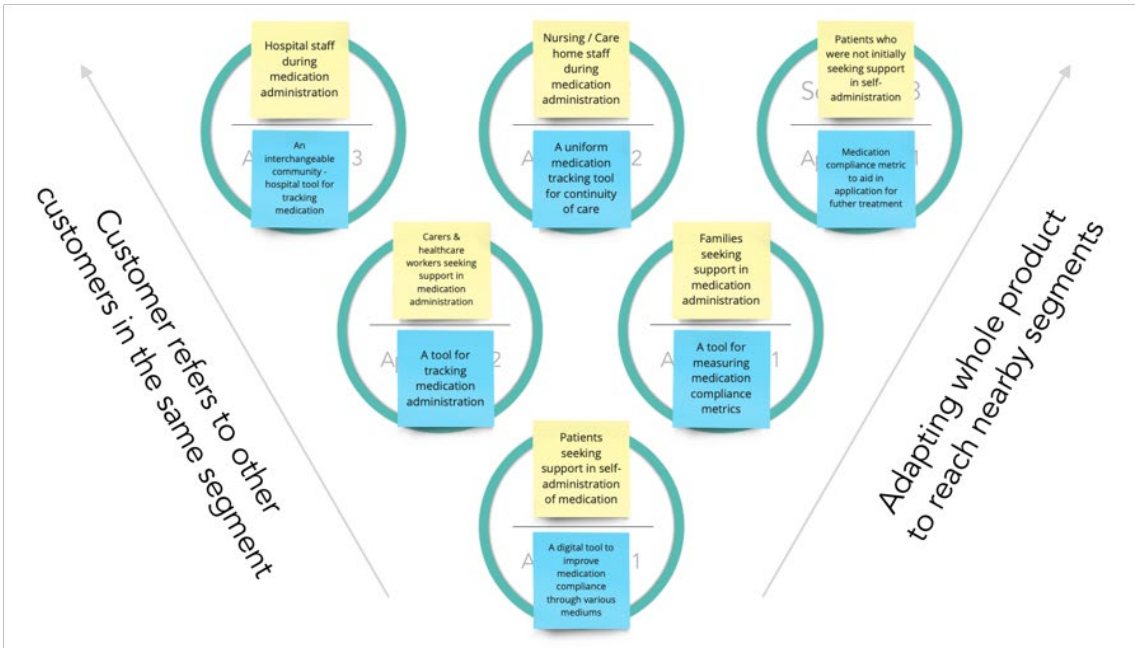


Appendix F: Business Model Research (62,63)

Value Proposition Canvas



Bowling Pin Strategy



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