

An Understanding of How Technology Can Assist in the Epidemic of Medicine Nonadherence with the Development of a Medicine Dispenser

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ABSTRACT

Background: Medication non-adherence is an ever-growing issue that if not dealt with, could have severe consequences. Methods to attempt to improve adherence in patients have been considered, including alternative treatment plans and medicine dispensers. The use of technology in the healthcare field has helped the field advance in many different ways. This paper aims to understand whether the use of technology could be a solution to non-adherence to medicine through the development of a medicine dispenser. **Methodology:** The project focuses on the design and development of a low-cost automatic medicine dispenser. The medicine dispenser is divided into two parts: the *dispenser* and the *alarm system*. The dispenser section stores and releases the medication, while the alarm section notifies the user when it is time to take their medication and which medication to take. The project works by the user first specifying precise times for each of their medications (for example, the first drug is due at 8 am and the second medication is due at 2 pm), and then the project stores this information in order to dispense the medication at these times each day. **Validation:** For the experiment, data was collected over a five-day period, with the three dispensing compartments and the alarm system being recorded each day. The alarm system is set to notify the user three times per day when medication is required. This alarm system was observed to see if the buzzer alerted at the time of medicine, as well as the correct LED of the dispensing compartment, and whether the LCD screen displayed the medication reminder message. The dispensing compartments were evaluated based on whether the sensor identified the user's hand and whether the medication was given appropriately in a timely manner. **Conclusion:** The primary conclusions are that technology, such as the usage of a medicine dispenser, can be demonstrated to be a valuable tool in combating medicine non-adherence through research and experimentation. The 5 days test with the medicine dispenser demonstrates the efficacy and feasibility of technological interventions. Every day, the device's alarm system could notify the user when it was time to take their medication (i.e., at 8 am, 2 pm, and 8 pm). The results of the project highlight how the medicine dispenser developed in this project has proven to have potential for combating non-adherence in relation to the factors of forgetfulness and complex regimens. Further

investigation can be conducted to gain a more detailed an accurate insight, as well as future improvements to the device to help other factors of non-adherence.

Keywords: Medicine Dispenser, Technology Assistance, Low-Cost Health Support, Personalized Care.

INTRODUCTION

According to Public Health England, more than 26% of adults in the UK take prescribed medication [1, 2]. Medication is used for a variety of treatments, from short-term antibiotics to long-term chronic illness treatments. Medicine has become a vital part of a lot of patients' treatment regimens. However, despite many patients relying on medicine for their treatment, many do not adhere to their treatment plans.

In this context, *Medication NonAdherence* is defined as "the extent to which patients take medications as prescribed by their healthcare professionals" [3]. It has become one of healthcare's biggest issues in modern times, with around one in four people not adhering to prescribed drugs [4-6]. Medicine nonadherence can materialize in many ways, from patients refusing to follow medical professional recommendations, patients misunderstanding or lacking means to follow health-related advice, to patients choosing against adhering for reasons entirely rational [7]. It can be divided into two main categories: *Primary NonAdherence* (PNA) and *Secondary NonAdherence* (SNA). PNA happens when a patient is given a new prescription and fails to get the drug within a reasonable amount of time. Whereas SNA happens when a patient collects a prescription but does not use the drug as directed [8]. This dissertation will be exploring SNA in the way patients forget or struggle to take their medication due to a complex regimen.

There have been different types of interventions created to try and assist medicine non-adherence. These include trying to find alternative treatment methods such as *Cognitive Behavioral Therapy* (CBT) instead of medication for mental health issues, regular reviews between healthcare professionals and patients to determine if the patient is benefiting from the medication, setting alarms when medication is due to remind patients to take their medication, and medicine dispensers that store and automatically dispense medication for the patient [1, 2].

Technology advancements have transformed healthcare into a more accessible, efficient, and effective industry. From digital records of a patients' medical history - i.e., Electronic Health Records - to robotic-assisted surgeries, technology has become a vital part of many healthcare professionals' day-to-day lives. Despite the fact that healthcare has numerous advantages, many people are concerned about its ethical implications. For example, some wonder whether achieving greater efficiency will not come at the expense of meaningful human interaction in the context of care [9]. Whilst there are many implications of technology in medicine that can be discussed, this paper will focus on how technology has assisted medicine.

Aims and Objectives

This paper aims to reflect on how technology has assisted the healthcare industry, through the design and development of a medicine dispenser that can be used to reduce medicine non-adherence. To achieve this several objectives must first be achieved:

- Understanding the purpose behind the project, including why people require medication, factors that can cause a person to not adhere to their medications, the implications of a person not adhering to their medication, and how medicine dispensers assist in tackling nonadherence.
- Provide an insight into how technology has currently helped the healthcare industry, including any advancements and drawbacks.
- Develop a device that will dispense medication at certain times throughout the day.
- Trial the device over a period of time to test its accuracy and record all the data and any observations.
- Produce results of the data collected and draw a conclusion based on the findings.

Motivation and Contribution

Noncompliance with medication regimens is an ever-growing problem, not in just the UK but across the world, and has been identified as a major public health issue that imposes a considerable burden upon healthcare systems [10]. In order for a definitive solution to be found to non-adherence, it is important to understand why it happens and first create solutions to these problems individually. Key factors of nonadherence are forgetfulness and confusion due to cognitive impairments and mental issues. These can show in ways such as, patients forgetting to take their medication at the right times, or at all, and patients being overwhelmed due to being required to take several medications a day which can result in patients being confused and taking the wrong medication.

This project allows further insight into research for medicine nonadherence by providing an understanding of how and why adherence happens and looking at a solution to the key factors through the development of a medicine dispenser. This is an important part of medicine nonadherence research as it allows an understanding of the factors of medication adherence, but also provides a low-cost and accessible solution for those who suffer from the key factors of non-adherence. This can be reviewed and developed to create more solutions across the other ways in which nonadherence happens.

Paper's Organization

- *Section 2* introduces the project by providing fundamental background information about the purpose of the device and the importance of medication adherence to help the reader understand the motivation and contribution of the paper. This chapter also highlights the main aims and objectives aspired to be achieved in this paper.
- *Section 3* includes a detailed literature review providing an in-depth analysis of medical nonadherence, why a person would be prescribed medication, and reasons why a person may struggle to take multiple medications or medications at a specific time each day, as well as the implications of not adhering to medication. Furthermore, this chapter will also provide insight into technology in healthcare, current medicine dispensers, their benefits, and limits.

- *Section 4* provides the development of the hardware and software for the dispenser in this paper. This chapter also requires the measures and methods used for the trial and observation of the device, including how it will be observed, for how long it will be observed, and any benefits or limits.
- *Section 5* shows a detailed account of the trial for the device, including the overall results, providing a review of the accuracy of the device and any evaluations performed.
- *Section 6* discusses the results of the project and highlights any important findings and how this device will benefit users. The chapter concludes with a review on the strengths and limitations of the paper.
- *Section 7* closes the paper by providing an overview of the previous chapters and any important results discovered in the study, also providing recommendations for future research in this area.

BACKGROUND

This Section includes an in-depth literature review which is split into three sections. The first subsection will be focusing on understanding medicine non-adherence, looking into the short-term and long-term implications that medicine non-adherence has but also looking into some of the causes behind medicine non-adherence, with a focus on cognitive impairments and chronic illnesses. The second sub-section reviews technology in healthcare to allow the reader to understand how technology has helped the healthcare industry advance, from databases to web-based consultations, this section will also review current technology that has assisted in combating medical nonadherence currently. The final sub-section will review the most promising method of combating medical nonadherence, medicine dispensers.

Understanding Medicine Nonadherence

Patient adherence is critical to the effectiveness of any medical treatment; therefore, nonadherence is an issue in healthcare for a variety of reasons. First of all, it has an impact on the outcome of their treatment plan; if a patient does not take their prescription appropriately, they have a lower chance of complete recovery. Sabate et al (2003) articulates that there is strong evidence to suggest that patients who suffer from chronic illnesses have difficulty adhering to their medication regimens, and poor adherence lowers a patient's quality of life, as well as resulting in both medical and psychological consequences of diseases [11]. Furthermore, nonadherence affects the cost of the health system, studies have analysed the economic impact of nonadherence and the results showed that there was an increase in total healthcare costs by more than 80%, as well as an increase in pharmacy costs by more than 70% [12]. Medication nonadherence is estimated to cost the *UK National Health Service* (NHS) over £500 million per year, which prevents the funds from being used for additional medical treatment and research [13]. Finally, since healthcare outcomes cannot be accurately assessed if they are primarily determined by resource utilization indicators and intervention efficacy, adherence is also a crucial moderator of the effectiveness of the health system. If adherence rates are not taken into consideration during project design and evaluation, it will be impossible to attain the population health outcome anticipated by treatment efficacy statistics [14]. Understanding factors that contribute to medical nonadherence is crucial for developing effective interventions.

There have been several studies completed to gain an understanding of and examine the various patient factors that influence the patient's willingness to follow their medical regimen. The categories that these factors fall under include *mental state*, *physical health*, *behavior/attitude/habits*, and *knowledge/beliefs* [15]. According to Gold et al (2006), one major element observed in many patients was the asymptomatic character of the diseases, as people suffering from diseases with no/hardly evident symptoms frequently did not follow their drug regimens because they believed their illnesses were not impacting them [16]. Kardas et al (2013) suggest that a factor for nonadherence is the social stigma surrounding the disease being treated, diseases such as HIV/AIDS have a negative stigma even in modern society, and those suffering from the disease may feel embarrassed, not wanting people to know about it or could even be refusing to believe they have the disease [17]. Another factor that influences patient adherence is the dosing schedule. For example, an elderly patient may adhere better to a simple dosing schedule that includes taking all of their medication at the same time in the morning, rather than having to take one dose in the morning and one dose at night [18]. If a patient is obliged to take numerous types of medication throughout the day, a medical regimen that involves more than one medication per day may present additional complications.

Among the many factors that can contribute to medical nonadherence, forgetfulness is the most common. Unni and Farris (2011) surveyed a sample of Medicare enrollees of ages sixty-five and over concerning reasons behind nonadherence to medicine [19]. According to the findings of this survey, several individuals suffered from unintended non-adherence due to forgetfulness. Forgetfulness in patients can develop for a variety of causes, including cognitive impairments and mental health issues. Cognitive impairments can have a significant impact on a patient's medication adherence; daily drug administration necessitates a certain degree of cognitive function, such as working memory and a good attention span [20]. *Mild Cognitive Impairment* (MCI) is a condition in which someone has minor problems with mental abilities such as memory or thinking and it is estimated that between five and twenty percent of adults over the age of sixty-five have MCI (Alzheimer's society, 2023) and whilst MCI is not a form of dementia, there is more likelihood of a person suffering with MCI to develop dementia [21]. Symptoms of cognitive impairments can differ from individual to individual, however, there are specific symptoms that affect the majority of patients who suffer from cognitive impairments, such as memory issues and attention spans, therefore making it harder for the individuals to do daily tasks, including taking their medication correctly. Hudani and Rojas-Fernandes (2008) provided a review on poor adherence to medication for patients with cognitive impairments that concluded hypertensive patients who had poor adherence to beta-blockers had a four-and-a-halftime increased risk of coronary heart disease [22]. Mental health issues can also affect a patient's adherence to medication, as studies have revealed that patients who suffer from depression are three times more likely to exhibit nonadherence to medical recommendations than those without depression (DiMatteo et al, 2000 – [6]). Bulloch et al (2006) surveyed over five thousand adults to report the frequency of noncompliance with antidepressants, as well as the reasons for noncompliance [23]. Their results showed that 41.7% of participants reported noncompliance and of that 41.7%, 64.9% said that forgetfulness was their reason for not adhering to their medication. Forgetfulness is a common trait among those with mental health issues, people who suffer from *Attention Deficit Hyperactive Disorder* (ADHD) tend to forget important things, such as taking medication, due to ADHD impacting their working memory [24].

Along with the implication of the medication not working, medicine nonadherence can have dire consequences on not only the patient but the healthcare industry. The NHS digital annual report of 2018 revealed that along with the high-cost implication, medicine nonadherence was responsible for over 50,000 emergency hospital admissions. This can put a strain on the healthcare workers as well as prevent those in critical situations from getting the emergency support they need. Furthermore, nonadherence to medication can have severe long-term consequences that consumers may not be aware of, a study conducted by DiMatteo et al (2002) discovered that medicine nonadherence was linked to increased mortality rates for patients with chronic illnesses, this included patients who do not take their medications at the same time each day and patients who did not take the correct dosages [5]. According to Tolkoof-Rubin (2008), individuals with *Chronic Kidney Disease* (CKD) who have poor medication adherence are at a higher risk of developing problems such as chronic anemia, cognitive dysfunction, and congestive heart failure, which can lead to death from the build-up of fluids and waste products in the body [25]. Chapman and Horne (2013) analyzed medication nonadherence in the field of psychiatry, their findings highlight how nonadherence is a global challenge for psychiatry and how nonadherence can cause patients poorer outcomes, such as hospital admissions, suicide, and mortality [26].

Technology in Healthcare

From *electronic consultations* to *illness management* via mobile phones, technology has become a vital aspect of healthcare. Consumers and many other areas of the healthcare industry have quickly welcomed healthcare technology. Helping emergency services is one way that technology has helped the healthcare profession. Since the incorporation of technology, first responders have received improved training and more advanced equipment to aid not just first responders but also emergency patients. The development of IP-based security systems, which send real-time alerts to a central monitoring system, is one example of technological advancements for first responders. These systems have the capability to automatically notify first responders when an emergency occurs [27]. The monitoring system is then able to contact the required emergency service (such as an ambulance/paramedic), allowing them to arrive at the scene as soon as possible. This advancement can be considered more effective than manual notification between the person receiving the emergency and the emergency service required, as it provides an accurate location of the emergency so reduces human error, such as if the receiver gives the emergency service the wrong address or there is a communication barrier.

Medical detection technology is another way that technology has aided healthcare. Healthcare specialists are continually researching diseases to try to uncover common elements, such as symptoms or the age range that the disease targets, as well as remedies. Artificial intelligence is one way that technology has aided healthcare practitioners in their studies. Artificial Intelligence is described as “*the science and engineering of making intelligent machines*” and has assisted in disease research through a subfield known as machine learning [28]. Deep learning algorithms have been used for disease prediction, such as cancer diagnosis prediction. Using disease data collected by medical professionals throughout the years has allowed for machine learning techniques to be applied to the data for disease learning predictions, such as heart disease prediction [29]. Through the identification of regularities or patterns in data using computer algorithms and the classification of data into various categories, machine learning algorithms have the capacity to find regularities or hidden patterns in data sets. Ootom et al., in

[30] introduced a smartphone application that uses machine learning algorithms for real-time diagnosis and monitoring of patients with *Coronary Artery Disease* (CAD). Their software was able to predict heart disease issues from clinical data entered by medical personnel and through the use of wearable sensors. Machine learning algorithms used in their application included classification algorithms; *BayesNet* and *Support Vector Machines* (SVM). Their research concluded with 100% detection accuracy. This type of advancement in healthcare technology is greatly beneficial for not only the healthcare professionals but also the patients as it allows for fatal diseases to be noticed a lot quicker and potentially saves patients' lives.

Because of technological advancements, medical practitioners can now use innovative video and webbased conferencing tools instead of relying primarily on in-person counselling approaches. This kind of progress in medical technology has been enormously valuable, particularly in recent years during the pandemic, when face-to-face consultations were extremely limited. *Virtual consultations* have been viewed by many as a partial solution to the complex challenges of delivering healthcare to an aging and increasingly diverse population [31]. They allow for accessibility for patients who are unable to travel or do not have the time to attend an in-person consultation, whether it is due to personal or professional reasons. Virtual consultations also allow for a better experience for patients, as they can be done from the comfort of the patient's home as opposed to a medical professional setting, this may allow for the patient to feel more open to talking about their situation with the professionals. Furthermore, virtual consultations provide a decrease in the waiting time for a patient's diagnosis and for treatment to begin, as well as allow for after-hours health coverage to be possible [32]. An important implication for virtual consultations is that it relies on both the healthcare professional and the patient having access to a technological device, which may not be possible for those in poverty. Furthermore, it limits the ability of the professional to perform a physical examination on the patient if required. As well as the requirement for technological devices, these consultations would require both users to have a good internet connection throughout the whole meeting, which may be difficult depending on the situation, for instance, the connection could be disrupted if several individuals are simultaneously using the internet in the patients home during the session.

Despite the fact that each technological development in healthcare has pros and cons of its own, it is vital to consider technology in healthcare as a whole to determine whether these developments are having a favorable impact on the healthcare sector. One negative aspect of technology in healthcare is due to technology storing crucial medical data, it exposes systems to the risk of hacking, which could result in the disclosure of sensitive data. Furthermore, if confidential data has been compromised, it can lead to inaccurate research or medical judgments. For instance, incorrect diagnosis or treatment could result from data that has been removed or manipulated [33]. Another drawback of technology in healthcare is that any new development necessitates extensive user training, which would take a lot of time and money to do for each healthcare practitioner. Despite technology devices having some drawbacks, many technological innovations have been integrated into healthcare well, and as seen through previous examples, have resulted in a more effective and high-quality healthcare industry [34]. Current innovations can also be used to improve individual issues that the healthcare industry still faces in modern times, such as medicine nonadherence and disease treatment.

Methods to Non-Adherence

To combat non-adherence, healthcare professionals and systems have begun to implement a range of methods aimed to support patients in adhering to their treatment plans. One method that has been used is *patient education* and *counselling*. Healthcare providers have a responsibility to inform their patients about the importance of adhering to medication, including informing the patient of the benefits and risks. Taibanguay et al (2019) composed a study of one hundred and twelve patients with arthritis to examine the effects of patient education on medication adherence and their results concluded that patient education does significantly improve adherence [35]. However, this method of treatment improves intentional nonadherence for patients who do not want to or believe they don't need to take their medication and does little to improve adherence for patients who struggle with unintentional non-adherence.

Simplifying medication regimens is one method designed to combat non-adherence. As previously mentioned, many patients who have a complex regimen of taking multiple medicines throughout the day tend to not adhere to their regimen. An intervention method for this specific problem is to simplify the regimen. One way to simple a medicine regimen is to combine multiple medications into one dosage to form a "*polypill*", studies have suggested that adherence to polypill therapy was significantly higher than multiple pills [36]. However, this solution method is not always possible, as patients with long-term chronic illnesses or patients who are required to take more than ten medications a day may not be able to simplify their medicine regimens and therefore this solution would not benefit their situations.

Another method that has been implemented is *mobile health interventions*, such as medication reminder apps. Medication reminder apps work by patients creating daily reminders that will alert the users when it is time to take their medication. One example of a medication reminder app is the *Medisafe app* which was designed by *The Shor Brothers* [37]. The app has several features to ensure the user takes their medications; a medication timer, a refill warning, a possible drug interaction warning if a user is taking multiple medications at once, and a family medicine tracker to allow family members to keep track of each other's medications. This app provides a free solution for users to take their medications and can also provide notifications for users who need to consistently take insulin and check blood sugars, the website also provides information on medications so users can get a better understanding of what they are taking. However, one issue with the app is that if the user's phone is silent, they might miss the notification [38]. Additionally, since the app is linked to the user's phone rather than a device that automatically administers medication, users are required to manually go and take their medications. As a result, if a user is in a different room from their medication when the alert sounds, they may silence the alert under the mistaken assumption that they will take the medication when they move into the other room but may still forget to do so.

In this context, *medicine dispensers* have been also designed to improve nonadherence for patients with complex medication regimens that cannot be altered or patients who do not adhere to their medical regimens due to forgetfulness. There have been several forms of medicine dispensers designed to allow patients to select the one they feel is better suited for their needs. One type of dispenser designed is the 7-day pill box, these consist of a box with different sections that are labelled with each day of the week and allow for the patient to

manually observe whether they have been adhering to their regimens or not [39]. This style of design is useful for patients who are disorganized or cannot remember if they have taken their medicine because it keeps everything in one location while allowing the user to check if they've been taking their medication consistently. While this type of dispenser addresses some aspects of adherence, there are still implications of this design that may not help patients improve their adherence; this type of dispenser still requires the patient to manually remember to take their medications each day while also expecting the patient to manually fill the box up each week; and this type of dispenser would not benefit patients with mental health issues or cognitive impairments because it is too much of an independent method.

Another type of design is a *smart medicine dispenser*. Smart medicine dispensers work by a user receiving a prefilled medicine dispenser, whether it is filled by a caregiver or a pharmacy, and the device will dispense medication at the required time throughout the day. Once it is time for the patient's medication, the device will make a noise to indicate that it is time for the medication. Some devices allow for an alert system that will inform a specific person, such as a caregiver if the patient has not taken their medications on time, this allows for the medication to be tracked so healthcare professionals can see whether patients are adhering to their medicine regimens whilst also providing a reminder solution for those who forget to take their medication. As medication dispensers are relatively new to the sector, there are a limited number of commercially available devices for consumers.

MATERIALS & METHODS

This section provides the development of the project as well as the measures and methods used for experimentation.

System Architecture

The work presented here focuses on the design and development of a low-cost automatic medicine dispenser. The medicine dispenser consists of two sections, namely *the dispenser system* and *the alarm system*.

The dispenser section is where the medicine is stored and released, and the alarm section is what alerts the user that it is time to take their medication and which medication to take. The project works by the user initially setting specific times for each of their medications (for example, the first medication is due at 8 am and the second medication is due at 2 pm), then the project will store this information to dispense the medication at these specific times each day.

- The project includes *3 dispensing compartments* and therefore allows for *3 different medications* to be stored and dispensed and allows for users to put multiple times for a medication if they are required to take several throughout the day.
- Each dispensing section contains a *proximity sensor*, located at the bottom of the compartment and *two servo motors* that are attached to the storage compartment, as well as an *LED* that is used to inform the user which of the medications they are required to take.
- The alarm section works through a *real-time clock* that tracks the seconds, minutes, and hours – namely *s*, *min* and *h* - of each day. Once the time that the user selected for medication is reached, the alarm will alert the user through a *buzzer* and a *flashing LED light*.

- The *buzzer* is used to get the attention of the user and the LED light is used to indicate which medication the user should be taking at this time. The alarm will output until it is switched off by the user through a button located near a *Liquid Crystal Display* (LCD) screen.
- The *user* will then be *required to place their hand* under the flashing LED light compartment to dispense the medication. Once the user has placed their hand under, the proximity sensor for that dispensing compartment will detect the hand and trigger the servo motors which will release the required dosage for that medication.
- A *green LED* will *flash* to inform the user that the medication is dispensing.

Hardware & Software

As previously mentioned, the system is made of two main hardware components.

1. The first is the dispenser, which contains an *Arduino Nano Board*, *3 proximity sensors*, *6 servo motors*, and *3 LED lights* that were all connected together on a *breadboard* through *jumper wires* as demonstrated in Figure 1 (left panel).
2. The second is the alarm, which contains another *Arduino Nano Board*, *3 LEDs*, a *Liquid Crystal Display* (LCD) screen, a *Real-Time Clock* (RTC), and a *button* which were all connected to a *breadboard* using *jumper wires* and *resistors*, as shown in Figure 1 (right panel).
3. The Arduino Nano was selected as it has built-in *Bluetooth* and *Wi-Fi modules* that allow for *wireless connectivity*; therefore, the project can be portable and placed in various locations without the requirements of a computer and the device has the ability to be powered up via socket plug, device, or portable charger. Furthermore, the Arduino Nano was selected due to its compact nature, so it does not take up much room. For the software, the code was written in C/C++ and then compiled using the Arduino IDE.

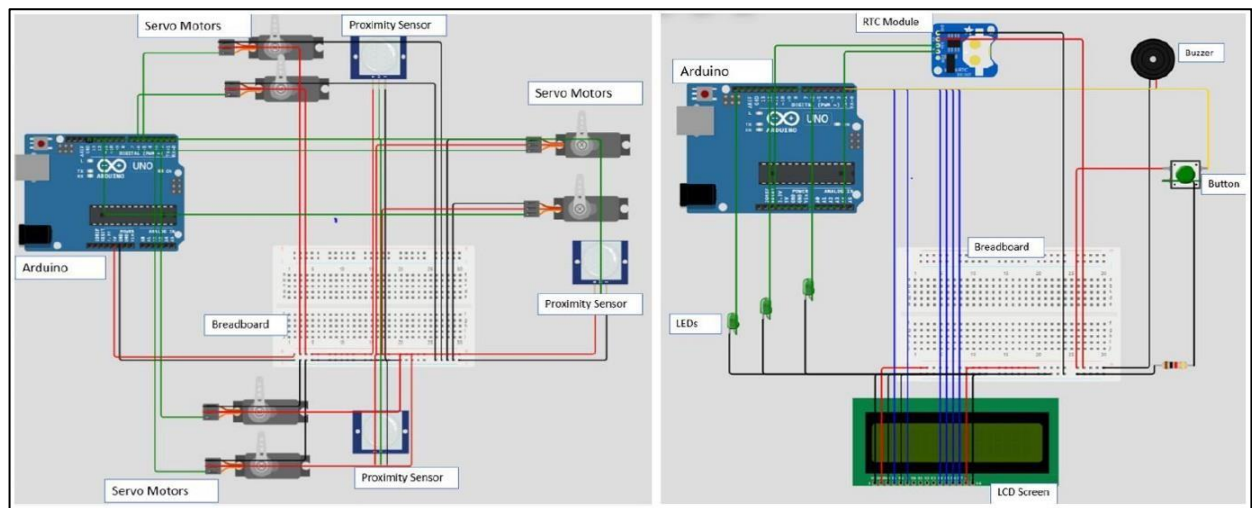


Figure 1. The Dispensing System Circuit (left panel) and the Alarm System Circuit (right panel).

For the dispensing component, 6 servo motors were connected to the Arduino which were used to separate and dispense the medication.

Each dispensing compartment contained two servo motors that were placed into the slots made in the storage pipes, each motor was placed at a distance to allow for the required dosage of the medication to be separated from the rest of the medication.

The servo motors work by containing aluminum covers that are placed on top of the motors and inside the dispensing tube, when the motors are triggered, they will move out of the pipes at a 90° rotation, the motors will then wait for a couple of seconds and will then move at a 90° rotation back into their place once the medication has been released.

In order to only allow for the correct dosage of the medication to be released, there is a few-second delay between the 1st motor moving and the 2nd and the gap between the two motors was measured to be the average size of a prescribed tablet which is between 11-22 mm [40]. For this dispenser, the distance between the two motors is 15.2 mm. The motor placed higher up the dispensing pipe will begin moving first and once this motor has returned to its original position, the motor at the bottom of the dispensing pipe will then begin to move, once the medication has been released into the user's hand, this motor also moves back into place.

A proximity sensor is also attached to the bottom of the dispensing compartment. The proximity dispenser works by detecting movement at a close distance, in this context the movement would be the user placing their hand under the dispenser. Once the sensor detects the user's hand, it will then send a signal to the Arduino, which will send a trigger to the two motors attached to that dispensing component.

For the alarm component, an *RTC DS3231 Module*, an *Arduino Nano*, a *16x2 LCD Screen*, 3 *LEDS*, a *button*, a *buzzer*, and 4 *resistors* were all connected together on a breadboard with jumper wires and powered using a portable charger. This component is placed towards the top of the medicine dispenser box, and the *LEDS*, *buzzer*, and *LCD screen* are placed on the outside of the box for the user to see.

The *RTC* module is used to track the time throughout the day, so that the *Arduino Nano* board knows what time it is. The *Arduino* is programmed so that once the *RTC* module detects the required times, a signal is then sent to the *Arduino* which triggers the output signals for the *LED*, *buzzer*, and *LCD screen*.

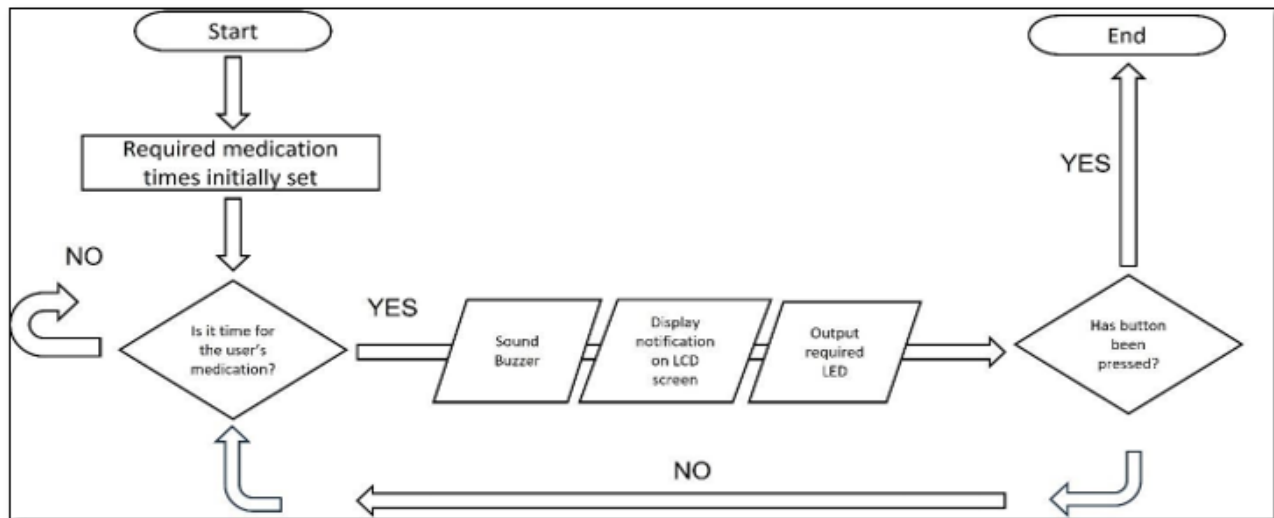


Figure 2: The dispensing algorithm.

The LCD screen will display the current time for the user and once the output signal has been triggered, the buzzer will begin to sound and the LCD screen will change to display a message, informing the user of which medication is due. Each of the LEDs is located at the top of the three compartments, so whichever compartment is for that alarm is which LED will flash at that time. This will continue until the user manually presses the button located at the front of the dispenser. A flow chart of the main rational of this mechanism is reported in Figure 2.

Once the button has been pressed, the LCD screen will continue to display the current time and the LED/buzzer will switch off until the next medicine is due. A breakdown of the components of the device can be seen in Figures 1 to give visual representation of how the device is structured.

Design Optimization

As the aim of this work is to provide a technological solution to medicine non-adherence through the development of a medicine dispenser, the project was designed to be easy to use and practical. The device does not require any hard work from the user, as everything, including the due medication times, is pre-programmed into the device, the only work the user would have to do is refill the medication pipes every so often, and due to the pipe design, this would usually be every 28 days to a month.

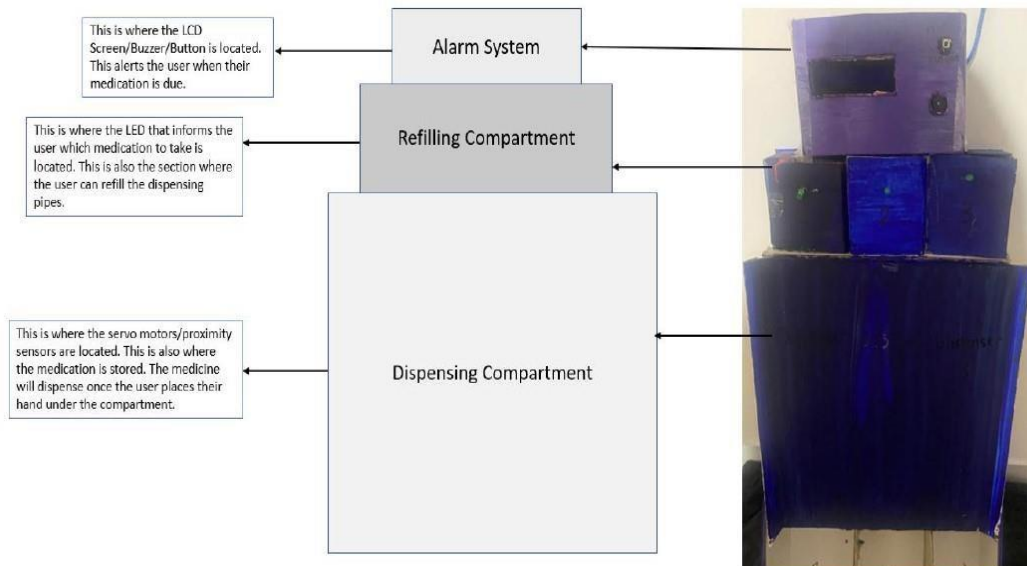


Figure 3: The Prototype of the Dispensing System.

Figure 3 shows the proposed design of the system, according to the schematic of Figure 1, whereas Figure 4 displays the main roles of the inner components of the dispenser.

Another design consideration implemented was to prevent medication waste, the device will only release the medication when the user requests it, by placing their hand under the dispensing compartment. This reduces medicine waste as if the user does not take their medication one day, the medication will remain stored in the dispensing pipe until requested, therefore a user will never unintentionally waste medication by it being dispensed and the user not taking it.

Preliminary Testing (Validation)

In order for the reader to understand how technology can assist in combating SNA factors of nonadherence, it is important to observe how the medicine dispenser designed in this paper can assist in nonadherence factors such as forgetfulness and misplacing medication. The way in which this will be demonstrated is through 5 days experimentation of the medicine dispenser.

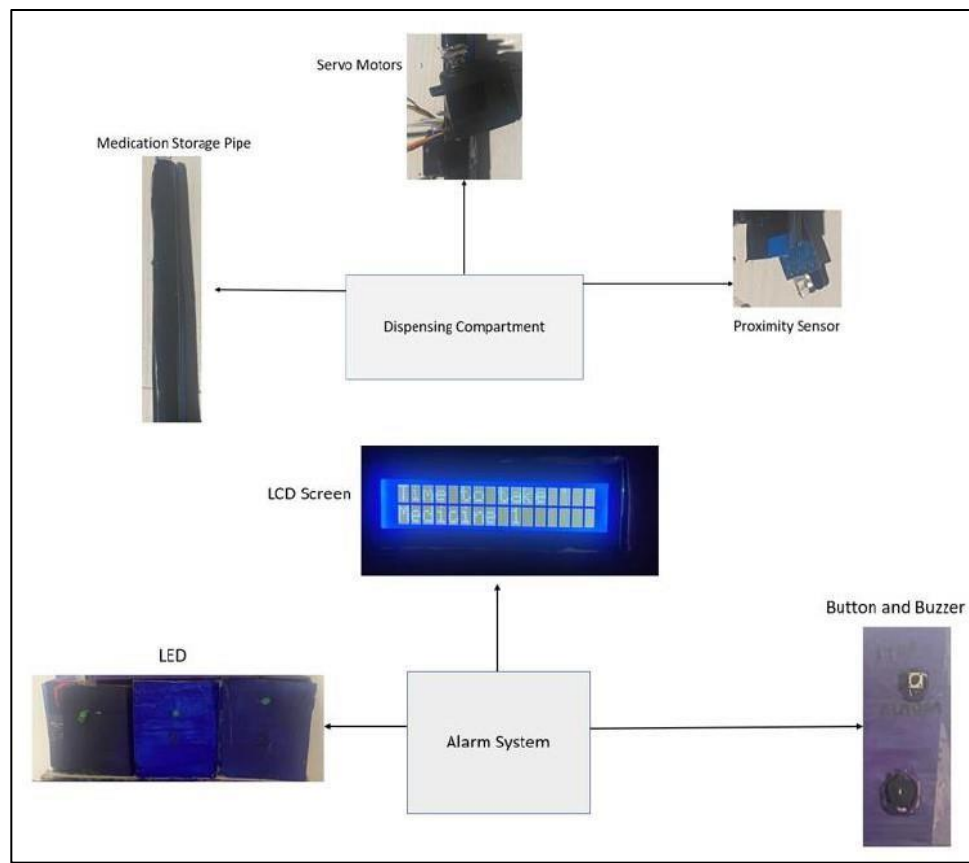


Figure 4. Details of the inner elements of the dispenser and of their roles.

For this experiment, the medicine dispenser was filled with “medication” (for practicality, in the experiment the medications were substituted with sweets) and each day we evaluated its performance: the final trials were a record of the 3 times a day in which the medication should have been dispensed.

For 2 of the dispensers, only 1 medication was requested, and for the other dispenser, 2 dosages were requested. We observed all the components of the dispenser, precisely:

- whether the alarm alerted at the correct times
- if the LED output for the correct compartment
- whether the LCD screen displayed the correct message to the user
- whether the medication dispenses the correct compartment and correct dosage.

Throughout the 5 days period, several factors were evaluated to determine whether a medicine dispenser has the ability to assist in *Medicine Non-Adherence*:

- *Success* - The first factor evaluated is the success of the trial, this was assessed through how many times each component of the device performed correctly and as expected over the five day period.
- *Ease of use* - Another factor that was evaluated was the ease of use of the device. As previously mentioned, this was an important consideration when designing the device as it would give the user a better experience and encourage them to use the product

more. Each device component was evaluated based on how simple it was to use and whether it performed as expected.

- *Consistency* - In order for the device to assist with non-adherence, it was important to evaluate the consistency of the device to ensure that the product works the same way each day. This factor was evaluated through a comparison of the way each component performed each day, any noticeable differences between days were recorded and an overall evaluation of whether the device proved to be consistent was also recorded.
- *Efficiency* - Similar to consistency, it is vital for the efficiency of the device to be evaluated to determine whether the device could be beneficial for users. In order for the efficiency to be evaluated, each component was analyzed based on their performance. A review of whether the component proved to be efficient or not was also recorded and an overall evaluation of the efficiency of the device was included.

Protocol and Data Collection

A *quantitative* and *qualitative* research design had been used for this study in which experimentation and evaluation of the device were performed. This approach was chosen to be able to measure the results and figure out the succession rate for the device as well as to determine whether this device would benefit a person suffering from *Medication Non-Adherence*. Data collection took place at the researcher's home and lasted for a period of five days in which the device was tested three times each day. Data from the experiment was manually recorded and any data collected was analyzed and placed into visual representation through tables.

RESULTS

Experiments' Results

For the experimentation, there was a 5 days period in which data was recorded, each day the three dispensing compartments were recorded as well as the alarm system.

Table 1. Experiments' Results.

Device Component	Medication 1 [out of 5]	Medication 2 [out of 5]	Medication 3 [out of 5]
Buzzer	5	5	5
LED	5	5	5
LCD Display	5	5	5
Dispensing Compartment	5	5	5
Total [%]	100	100	100

Table 1 displays the results for each component of the dispensing device and out of five, how many times they performed successfully throughout the experiment in relation to each of the three medications. The alarm system was programmed to alert the user three times a day, whenever a medication was due. The observation for this alarm system was to test whether the buzzer alerted at the time of medication, as well as the correct LED of the dispensing compartment, and whether the LCD screen displayed the medication reminder message. The dispensing compartments were recorded through whether the sensor detected the user's hand and whether the medication was dispensed correctly within a short period of time. For *Medications 1* and *3*, just one dosage was requested for the user; however, for *Medication 2*, two

dosages were requested. As a result, the dispensing compartment for *Medication 2* delivered medication twice in a few seconds.

As previously mentioned, the alarm component was expected to alert the user to take their medication at three different times throughout the day. The *1st alarm was set for 8 am*, the *2nd alarm was set for 2 pm* and the *final alarm (3rd) was set for 8 pm*. For each alarm, the buzzer was expected to alert, and the LCD screen was expected to display a medication reminder for which of the medications the user was required to take (e.g., “*time to take your first medication*”). Each medication had a designated LED light connected to the door of the refilling compartment to direct the user to which medication they were expected to take. Table 1 shows a set of preliminary results, according to the performance of the different components of the system.

Testing the Release of Medication 1:

Figure 5 displays the evaluation over the 5 days period for *Medication 1*. This evaluation examined each of the device components and their performance over the 5 days period for the medication that was first. This medication was expected to be taken at eight am each day.

Design Component	Evaluation of the five-day period
Buzzer	Each day, the buzzer alerted at 8 am and continued until it was switched off by the user. On the fourth day, the continuity of the buzzer was tested by the user ignoring the buzzer for two minutes, and throughout that time the buzzer remained alert until the user switched it off.
LCD Screen	Once the buzzer had alerted the LCD screen displayed a message that said, “Time to take your first medication.” This message remained on the screen for 1 minute and then the message would switch back to the current time. 
LED	The first LED (located at the left of the box and at the top of the first dispensing compartment) lit up until the button for the buzzer had been pressed. This happened continuously over the five-day period. 
Dispensing Compartment	Upon placing their hand under the dispensing compartment, it took five seconds for the medication to fall into the user’s hand. By the end of the week when the medication had lessened in the pipes, the medication time began to increase to seven seconds as there was more space in the pipe.

Figure 5. Results of *Medication 1* release.

Testing the Release of Medication 2:

Figure 6 displays the evaluation over the 5 days period for *Medication 2*. This evaluation examined each of the device components and their performance over the 5 days period for that medication which was expected to be taken at 2 pm each day.

Design Component	Evaluation of the five-day period
Buzzer	Each day, the buzzer alerted at 2 pm and only stopped once turned off by the user.
LCD Screen	Once the buzzer had alerted the LCD screen displayed a message that said, "Time to take medicine 2." 
LED	The second LED (located at the middle of the box and at the top of the middle dispensing compartment) lit up until the button for the buzzer had been pressed. 
Dispensing Compartment	Upon placing their hand under the dispensing compartment, it took five seconds for the first dosage to be dispensed and then two seconds later the second dosage was dispensed.

Figure 6: Result of Medication 2 Release

Testing the Release of Medication 3:

Similarly, to Figure 6, Figure 7 displays the evaluation over the 5 days period for *Medication 3*. This evaluation examined each of the device components and their performance over the usual 5 days period. This medication was expected to be taken at 8 pm each day.

Design Component	Evaluation of the five-day period
Buzzer	The buzzer alerted at 8 pm and remained until it was switched off by the user.
LCD Screen	Once the buzzer had alerted the LCD screen displayed a message that said, "Time to take medicine 3". This message remained for one minute and then switched to the current time. 
LED	The third LED (located at the right of the box and at the top of the right dispensing compartment) lit up until the button for the buzzer had been pressed. 
Dispensing Compartment	Upon placing their hand under the dispensing compartment, it took five seconds for the medication to fall into the user's hand. This timing remained the same throughout the five-day period.

Figure 7: Result of Medication 3 Release

Usability

Throughout the experimentation period, a usability evaluation was also conducted to determine whether this device would be a beneficial solution to non-adherence. Several factors were evaluated.

Ease of Use:

The experimentation allowed for an assessment of the ease of use for the device. This tested whether the device had a simple design that made taking medication easier for the users, as well as an evaluation of each section of the device to determine whether the device has an overall ease of use or whether there were some sections that a user might struggle with. Figure 8 displays the breakdown of the ease-of-use assessment.

Device Component	Evaluation
Alarm	The alarm component has a simple design in nature, the LCD screen displays the message in an obvious location to the user and the text is large enough for the user to read within a short distance. The button to turn off the buzzer and LED is noticeable and labeled well, so there are no issues in trying to figure out how to turn the alarm off.
Refilling	The refilling compartment was simple to use. The door of each compartment was labeled correctly with specifications for whichever medication belonged to that compartment. Upon opening the door, it was easy to refill the medication as the user poured the medication into the hole that was connected to the dispensing pipe.
Dispensing	Each dispensing section was separated from the other to prevent the user from placing their hand under the wrong one. The dispensing compartment only requires the user to place their hand under the dispensing pipe and then the medication would be released into the user's hand. Making the dispensing of the medication a quick and easy process for the user.
Overall Evaluation	The device has good ease of use. Upon assessment, it was simple to figure out what each compartment does, as they were all well-labeled. The device has a simple nature that makes it easy to use for everyone, even those with little technological experience.

Figure 8: Ease of Use Evaluation for the Device.

Consistency:

The experimentation also allowed for an assessment of the consistency of the device. This tested whether the device is able to perform the tasks effectively and repeatedly each day to allow an insight into whether this device would be able to assist users in correctly taking their medication. Figure 9 displays the breakdown of the consistency assessment.

Device Component	Evaluation
Alarm	The alarm component worked as expected. Each time a medication was due, the alarm component would alert the user through the buzzer, LED, and display a message on the LCD screen. This was repeated for each medication throughout the experiment.
Refilling	The refilling compartment remains the same each time and the user is able to refill their medication the same way anytime required.
Dispensing	Each dispensing section worked the same way, the user placed their hand under the compartment of the required medication and after several seconds the medication was dispensed into the user's hand. The dispensing component released the correct dosage for each medication throughout the five-day period. This method of dispensing the medication remained the same throughout the week and required the user to repeat the same movement of placing their hand under the medication.
Overall Evaluation	Throughout the experimentation, the medicine dispenser exhibited remarkable consistency. The dispenser consistently dispensed the correct dosage of medication for each compartment with the programmed setting. Furthermore, the dispenser consistently adhered to the designated alarm schedule, ensuring the correct timing of medication.

Figure 9: Consistency Evaluation of the Device.

Efficiency:

An assessment of the efficiency of the device was also completed during the experiment. This tested the functionality of the device to see whether it performed accurately and effectively. This allows for an insight into whether the dispenser has the potential to be a reliable and effective tool in combating medicine non-adherence. Figure 10 displays the breakdown of the efficiency assessment.

Device Component	Evaluation
Alarm	The alarm component proved to be efficient through its precise and timely medication reminders. The alarm was able to alert the user at three required times each day throughout the five-day experiment.
Refilling	As the refilling compartment does not have any automated functionality, it was not possible to assess the efficiency of this component.
Dispensing	Over the five-day evaluation period, each dispensing compartment demonstrated efficiency by ensuring the safekeeping and precise delivery of the medication. The dispensing mechanism efficiently released the medication with a high level of accuracy and ensured the medication was readily accessible when the user requires it.
Overall Evaluation	The device demonstrated exceptional efficiency through automated functions and medication administration. The device ensured the user was aware when their medication was due as well as making the medication readily accessible for when it was required.

Figure 10: Efficiency Evaluation of the Device.

DISCUSSION

The Key Findings

To begin, the investigation's key findings are that, through research and experimentation, technology can be proven to be a useful tool in combatting medicine non-adherence, such as through the use of a medicine dispenser. The 5 days experimentation of the medicine dispenser highlights the effectiveness and feasibility of technology interventions. Each day, the alarm system in the device was able to alert the user when it was time for them to take their medication (8 am, 2 pm and 8 pm).

Table 1 depicts how all of the device's components had a full five-day success rate in the research; thus, the results for this experiment conclude that the device had a total accuracy rate of one hundred percent.

In order for the device to be used in the next stage of experiments it was first important that the device met the usability requirements to prove that the device can be a suitable and reliable solution to medicine non-adherence. This was achieved through evaluating the ease of use, consistency, and effectiveness of the device. Figures 5, 6, and 7 display the results for the assessment of the components for each medication. These tables provide visual evidence for the output of the LED and LCD for each medication to allow the reader a better understanding of the way in which the product worked. Each table also provides information on how long each

medication took to dispense once the user placed their hand under the compartment. Figure 6 highlights how medication 2 had the longest dispensing time, *Medication 1* and 3 both had a dispensing time of 5 s, whereas medication 2 had a total dispensing time of 7 s. The reason behind this is due to the *Medication 2* providing two dosages which requires the dispenser to perform twice, in comparison to *Medications 1* and 3 which only provided one dosage and therefore those dispensers only have to perform once. Despite *Medication 2* having a slightly longer dispensing time, each medication was successfully dispensed into the user's hand in under 10 s of the user placing their hand there, which demonstrates the effectiveness of the device.

Figure 8 displays the *ease-of-use* evaluation for the *Medicine Dispenser*. This evaluation found that the medicine dispenser designed for this investigation had a simple design that allowed for an easy solution for people who have to take multiple medications. The overall evaluation concludes that each component of the device was easy to use and accessible for the user. Each compartment was welllabelled to ensure that the user had no issues in figuring out the device. The alarm system is easy for a user to find as it is located at the top of the device and contains the LCD screen, buzzer, and button. The refilling compartment is located at the middle of the device and can be noticed through the doors that divide each refilling compartment which are labelled "medication 1, medication 2 and medication 3" and each has an LED that is used to alert the user which medication to take. The refilling of the medication was also designed to be simple for the user, upon opening the doors of the refilling compartment, there is a hole that connects to the dispensing pipes, and all that is required of the user is to pour their medication in this hole. If a user is unable to do this, such as through cognitive illnesses, this can be done by a healthcare professional or a family member/carer. The dispensing component of the device also proved to be easy to use, the design of the dispensing component allows for 28 days/a month of medication to be stored, which means users would only have to refill their medication once a month. The dispensing compartment also displayed an ease of use through the dispensing of the medication, the device only required the user to place their hand under the compartment for several seconds and then the required dosage of medication was dispensed. This could be especially beneficial for users who have physical issues that would prevent them from being able to open a packet/bottle of medication, as the medication in the dispensing pipes is ready to take.

The *consistency* of the device was evaluated through the assessment of each component for each medication throughout the day, as well as an overall evaluation for the device. To assess the components, a comparison of the performance of each one over the 5 days was executed. Upon analyzing the comparison, the results demonstrated that the dispenser proved to be consistent through performing in the same way each time. The consistency of the device demonstrates how it can be a suitable solution for non-adherence. As seen in the results section, each component of the dispenser proved to be consistent over the five-day period. This suggests that the medicine dispenser is a reliable device as the device ensured that medications are dispensed at the designated times consistently, therefore minimizing the likelihood of missed or delayed doses due to forgetfulness. This regularity and adherence to a prescribed regimen addresses one of the primary hurdles to pharmaceutical non-adherence, and the device's reminder mechanism maintains consistency by actively reminding users to take their prescriptions as scheduled. The dispenser provides a physical method to prevent non-

adherence by providing an organized and reliable way to provide medication, particularly in cases where forgetfulness or complex regimens are prominent. The consistent use of the medicine dispenser for the three medications ensured that the medication dosages were able to be administered at the prescribed intervals. For medication one was due at eight am each morning, the alarm system went off as soon as the time reached eight. For this, the buzzer would sound, as well as the LED for the first dispensing compartment and the message on the LCD screen displayed "Time to take Medication 1", and this would happen at the same time each day. For the dispensing compartment, the medication would release within a 10-second period each time the user placed their hand under the required dispensing compartment. The device performed the same for medication two and three as well, the alarm system would alert the user and once the user placed their hand under each dispensing compartment, the system would again release the required dosage in under 10 seconds.

Finally, Figure 10 in the results chapter displays the evaluation of the *effectiveness* of the medicine dispenser over the five-day period. Like the other usability requirement evaluations, the effectiveness of the device was measured through an evaluation of each device component, as well as an overall evaluation of the device over the five days. The findings of this evaluation concluded that the device demonstrated excellent efficiency throughout the experiment. The dispenser's automated functionality ensured accurate and timely medication administration, which minimized the risk of missed or incorrect dosages. As mentioned in the literature review section, a key factor in medication non-adherence is forgetfulness and an important way of improving adherence rates is through consistent medication intake through the use of effective methods. By providing a consistent and reliable system for medication delivery, the device has proven that it can be considered an effective method for improving adherence rates.

Medicine Dispensers, Some Final Considerations

As previously mentioned, technology has already proven to be effective in assisting the healthcare industry through the use of disease management and web-based consultations. Current available medicine dispensers have also proven to have potential in assisting patients with non-adherence. The *Hero* medicine dispenser has already dispensed more than 70 million medications since its launch in 2018 and the *MedaCube* dispenser has already begun to be used in clinical studies for improving adherence [41, 42]. While both of these dispensers are among the most popular commercially available medication dispensers on the market today, the medicine dispenser proposed in this paper offers several advantages that the other two do not. Firstly, the dispenser designed in this paper was a low-cost design as opposed to the high costs of *Hero* and *MedaCube* and requires no upfront payment or monthly cost in order to be used. Secondly, the design of the dispenser for this paper is more accessible than both the *Hero* and *MedaCube*. The *MedaCube* dispenser requires the user to manually withdraw the medication from the device through a compartment and the *Hero* dispenser requires the medication to be dispensed into a cup, the device designed in this paper allows for the user to dispense the medication in any way they prefer. If the user wishes to dispense the medication in a cup, then they are able to place the cup under the compartment of the medication due, else if they wish to just use their hands, then they are able to just place their hand under the dispensing compartment. Unlike the other two dispensers, this dispenser is more accessible to those who have physical issues, such as shaking hands, because it does not require the user to have to open anything or move any objects in order for them to get their medication. Furthermore, unlike

the Hero dispenser, this device has several charging options, the user can either charge the device via socket, power bank or electronic device, whereas the hero device requires it to be plugged into a socket at all times. This is more beneficial for the user as if there is an electrical issue in the users home, such as a blackout, this dispenser will still work and can also be portable/be moved into different rooms, whereas if the user had the hero dispenser and there was an electrical issue, the user would not have access to their medication for as long as the issue continues.

Despite each medicine dispenser having their different qualities, all the dispensers have the same impact for the user, each one has the potential to improve SNA factors such as forgetfulness or complex regimens. Each dispenser allows for the user to store multiple medications, and each provides an alarm system that reminds the user when to take their medication. This furthers the investigation into whether technology can assist with medicine non-adherence as the medicine dispensers are a proposed solution to some of the key factors that cause non-adherence. Furthermore, the accuracy of technological medicine dispensers in comparison to manual dispensing demonstrates how the dispenser is more consistent. For a user to manually take their medication, they are required to be alert at all times, as they would either have to set a manual reminder on their electronic devices or constantly remember when their medication is due. As automatic dispensers consist of technological components, they are programmed to perform these tasks constantly, day after day, unless informed otherwise. The programming of the dispensers reduces the manual human error of manual medication dispensing as the program reminds the user when the medication is due and therefore, the user is able to go about their daily tasks without attempting to remember when their medication is due. Another strength of medicine dispensers in comparison to manual dispensing is that the medicine dispensers keep the medication stored in the device, therefore there is no concern about medication being misplaced or lost.

Pros of the Proposed System

A significant strength of this investigation is the exploration into a research area of medicine that has little research/investigation. This work has managed to provide insight into ways technology can assist in non-adherence that has not been investigated in depth. From this investigation, researchers will be able to have a better understanding of how effective technology has proven to be in assisting issues currently faced in the medicine industry, as well as how technology, such as the medicine dispenser, has the ability to assist with patients who struggle to take their medication due to forgetfulness/cognitive impairments or due to their complex medicine regimen.

Further to the results of this investigation, the experimentation of the medicine dispenser demonstrates how it is a device that has been proven to be simple, consistent, and effective in assisting users with taking their medication. Over the five-day period, the device showed a success rate of one hundred percent which shows the reader how effective the device can be. Additionally, the evaluation of each device component allowed the reader to gain an understanding of how each component works in helping the user take their medication, such as with the alarm system. The choice of five days for the experiment also highlights how the device has proven to have potential long-term consistency in assisting users, as each day the device performed the same tasks at the same times.

Additionally, due to the programming of the device, if a user's medicine regimen changes and they are required to change the times in which they take the medication, the coding of the device can easily be changed to suit the user's needs. The simplicity of the components is also a strength as if there is ever any issues with the device, the parts can easily be repaired or replaced.

Cons of the Proposed System

Although there are many strengths to the investigation, there are also limitations that have been faced during the research which would need to be considered in order to improve the quality of the investigation. The most important point to address is that whilst the experimentation demonstrated the consistency and effectiveness of the device, it has yet to be tested on human participants. Due to time constraints, it was not possible to get human experimentation conducted with the medicine dispenser. Therefore, the experimentation performed shows the potential of the device, it does not display a guaranteed impact on non-adherence for users. If the device was to be tested on a group of human participants, a more accurate evaluation of the device could be performed, as well as a further investigation into the ways in which it can assist people suffering from non-adherence.

Another limitation faced in the study is that, whilst the medicine dispenser is shown to be an excellent example of how technology can assist in combating medicine non-adherence, it can only assist in certain factors of non-adherence, such as forgetfulness and complex medicine regimens, and does not benefit users who suffer from non-adherence for reasons such as adverse side effects or lack of symptoms. Therefore, further investigation with other technological devices should also be considered when creating an overall solution to non-adherence.

A final limitation of the study is the experimentation duration. Whilst a five-day experimentation was enough time to determine the effectiveness of the device and to show the potential the device has for assisting in non-adherence, a longer experimentation may be more beneficial. For example, as the medicine dispenser has the ability to store up to a month of medication for the user, a month-long experimentation could take place to see how the device improves the user's adherence to their medication over the month.

CONCLUSION

The main aim of this research was to provide an understanding of how technological devices have the ability to assist in the epidemic of non-adherence to medicine, such as with the use of a medicine dispenser. This study's findings provide valuable insight into the significance of technology in addressing non-adherence and the effectiveness of the medicine dispenser. Technology-driven initiatives have the potential to increase medication adherence rates by offering established and reliable methods of administering medications. The findings also highlight the utility of technology in overcoming non-adherence challenges such as forgetfulness and complex regimens.

The research evidence indicates the efficiency of the drug dispenser designed for this study. The dispenser was successful in providing medication at the appropriate times, and the

integrated reminder system successfully encourages the user to take the medication when needed.

The objective to provide an understanding of how a medicine dispenser can be a solution to factors of non-adherence was successfully completed. Whilst the device was not able to provide statistical evidence of this through a human participant study, the evaluations of the five-day experimentation performed to demonstrate how the consistency of the device can provide a solution in reminding users to take their medication, and the simple design of the device allows for the taking of the medication to be a quick and easy procedure for the user, regardless of their complex regimen.

Future research recommendations include testing the device on human participants to acquire a better understanding of the topic, as well as implementing it in a healthcare setting to further understand its benefits. For instance, this device could be used in care homes that deal with patients with cognitive impairments to further experiment with how the device can help patients.

Another future improvement that could be developed is to create a notification system that communicates with the medicine dispenser and alerts the user or a family member/ carer on whether the user has taken their medication at the correct time. This could also be used by healthcare professionals to evaluate whether a patient is successfully following their treatment regimen or whether alternative treatment plans need to be considered.

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