Pill Assist

Using Principles of Design to Improve Medication Adherence among People Living with HIV/AIDS (PLWHA) in Ghana

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A thesis exhibition presented to OCAD University in partial fulfillment of the requirements for the degree of Master of Design in Digital Futures

Toronto, Ontario, Canada, 2022

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Abstract

People's lives are made easier through design and technology, whether it is a smartphone or a device that assists visually impaired people. This research explores new approaches to pillbox design for people taking medication. Pillboxes are meant to support patients with serious illnesses like HIV/AIDS for which regular medication-taking is necessary. Using electronics, experiments were conducted on different designs, forms, and structures of traditional pillboxes. This research uses a qualitative research and prototyping strategy to investigate the potential of good design on technological advancements to improve low medication adherence rates due to stigma for people living with HIV/AIDS (PLWHA) in Ghana, while also making medicine-taking a more private experience. The Pill Assist prototype is a wearable device that takes a traditional wallet design and transforms it into a dual-purpose medication storage and reminder system. This device assists people with pill-taking in a timely manner while keeping their status private. Pill Assist introduces new ways in which wearable design can be integrated into pill-taking and as a lifestyle solution. Findings from this study are an initial step toward applying good design principles and technology to develop solutions that cater to all stigma-related diseases.

Keywords: HIV/AIDS, people living with HIV/AIDS(PLWHA), electronics, prototyping, pillbox design, medication storage, discrete

Acknowledgments

Thank you:

Professor Kate Hartman, for the constant support and encouragement you gave me during my thesis project and for always keeping me focused and on track.

Dr. Kathy Moscou, for providing your deep insight and knowledge on my thesis subject matter as well as useful feedback and comments on my research.

To the **Digital Futures program and faculty** thank you for imparting me with knowledge from the wide range of classes I undertook while at OCAD and for challenging me to think critically.

Table of Contents

List of Tables

List of Figures

List of Appendices

1 Introduction

Adhering successfully to a medication regimen is vital in having a positive outcome on an individual's health, yet non-adherence remains an issue. Patients with ongoing complex medication regimens are more likely to deviate from a given regimen. Furthermore, people with chronic diseases have unique circumstances which could lead to non-adherence. Solutions need to be created which consider these unique barriers to adherence and can assist people in improving adherence. This research explores how applying certain design considerations may provide a unique way of addressing these issues.

The World Health Organization (WHO) defines medical adherence as the extent to which a patient follows medical instructions – taking medication, following a diet, and/or making lifestyle changes[1]. Medication adherence specifically deals with the process of seeking medical attention, filling prescriptions, and taking medication appropriately, among other things[2]. Adhering to medication is crucial to the success of a treatment plan while improving the underlying health conditions of an individual. Non-adherence, meanwhile, can lead to serious health consequences for an individual. Despite the importance of adherence to beneficial health outcomes, non-adherence rates remain high. In 2020, more than 20 million people in Sub-Saharan Africa (SSA) were living with HIV/AIDS, the highest number of people living with HIV/AIDS in the world. 73 percent of these people received antiretroviral therapy (ART)[3]. This is still some way below the target of 95-95-95 set out by the WHO to end the HIV/AIDS pandemic by 2030, where 95 percent of people living with HIV must be on an antiretroviral treatment plan (ART)[4]. Although sociodemographic factors (e.g., poorer adherence among older adolescents as well as those living in spaces with less privacy such as foster care or orphanages); individual factors (e.g., forgetfulness); and treatment-related factors (e.g., high pill burden) may contribute to patients' inability to adhere to antiretroviral therapy (ART), other

[1] Eduardo Sabaté and World Health Organization, eds., *Adherence to Long-Term Therapies: Evidence for Action* (Geneva: World Health Organization, 2003).

[2] Ibid.

[3] Geneva: Joint United Nations Programme on HIV/AIDS, "UNAIDS Data 2021," 2021, https://www.unaids.org/sites/default/files/media_asset/JC3032_AIDS_Data_book_2021_En.pdf.

[4] UNAIDS, "AIDS by the Numbers 2015," 2015.

challenges such as stigma, (especially in boarding schools), lack of clinical support and poverty have been cited as barriers to antiretroviral (ART) adherence in Sub-Saharan Africa[5]. Stigma is often overlooked as a barrier when design solutions are taken into consideration.

Stigma is defined as having negative views or prejudice towards someone based on a distinct attribute such as a mental illness, health condition, or handicap[6]. Erving Goffman defined stigma as an attribute that is deeply discrediting and one that precludes an individual from full social acceptance[7]. In the case of people living with HIV/AIDS (PLWHA), this leads to discrimination in all sectors of society such as healthcare, education, the workplace, families, and communities[8]. In the context of medication adherence, the perceived threat of stigma leads to different strategies that directly and indirectly impair proper treatment adherence[9]. The different strategies often involve finding different ways to conceal their medication. This makes it difficult to receive adherence support or causes people living with HIV/AIDS to disregard information that might aid in treatment adherence[10].

All of this seems to point to stigma being a major barrier to medication adherence, presenting the opportunity for more research on interventions for specific populations, such as people living with HIV/AIDS (PLWHA). This is an issue that may benefit from a design approach that assists in effective concealment strategies that do not interfere with adherence. The Pill Assist prototype is a

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[5] N. Ammon, S. Mason, and J.M. Corkery, "Factors Impacting Antiretroviral Therapy Adherence among Human Immunodeficiency Virus–Positive Adolescents in Sub-Saharan Africa: A Systematic Review," *Public Health* 157 (April 1, 2018): 20–31, https://doi.org/10.1016/j.puhe.2017.12.010.

[6] Jenev Caddell, "How to Cope With Stigma When You Have a Mental Illness," Verywell Mind, February 15, 2022, https://www.verywellmind.com/mental-illness-and-stigma-2337677.

[7] Erving Goffman 1922-1982, *Stigma; Notes on the Management of Spoiled Identity* (Englewood Cliffs, N.J. : Prentice-Hall, [1963], 1963), 6, https://search.library.wisc.edu/catalog/999472649302121.

[8] Lance Rintamaki et al., "The Role of Stigma Management in HIV Treatment Adherence," *International Journal of Environmental Research and Public Health* 16, no. 24 (2019), https://doi.org/10.3390/ijerph16245003.

[9] Ibid.

[10] Ibid.

wearable device that takes a traditional wallet and transforms it into a dual-purpose medication storage and reminder system. The device assists people with pill-taking in a timely manner while keeping their status private.

1.1 Motivation

For my research, I have decided to focus on Ghana for two main reasons. The first is that, as a Ghanaian, I have had the opportunity to observe how people living with HIV/AIDS are treated within the Ghanaian community. In some cases, people in our community who are recognized as living with HIV/AIDS, are not treated with respect and are shunned by others. In some circumstances, basic employment and health access rights are denied. Although this is not reflective of the whole nation, it is more prevalent in certain areas of the country than others. My hope is to improve that experience. Secondly, working as a Product Designer in Ghana has provided me with some insight into the country's product design landscape. Even though HIV/AIDS is more of a pressing concern in countries like South Africa[11], my lack of ties to the country makes coming up with a solution that people will be attracted to more challenging. However, as a Ghanaian, my personal insight into what people might like can better inform the design of the device.

1.2 Research Question

The main research question addressed by this thesis is:

> How might design and wearable technology be utilized to help people with a stigmatizing condition, such as HIV/AIDS improve medication adherence in a Ghanaian context?

The objective of this thesis is:

> To explore possible improvements to the design of medication adherence products to respond to the needs of different demographics and medical patients.

1.3 Scope and Limitations

The main challenge of taking on this topic of HIV/AIDS, stigma, and medication adherence is confidentiality and access to people within the HIV community. I recognize that the personas

[11] Geneva: Joint United Nations Programme on HIV/AIDS, "UNAIDS Data 2021."

created are not representative of the diverse people living with HIV/AIDS (PLWHA) and may not work for everyone. My aim is simply to contribute to the topic of HIV/AIDS stigma and technologies to support individuals that have HIV/AIDS.

For this research, I was not able to conduct any form of user testing due to time constraints, lack of access, and restrictions due to the COVID-19 pandemic. To evaluate the prototype I made, I created a design framework to evaluate the suitability of my prototype for people living with HIV/AIDS (PLWHA) while measuring it against existing medication adherence products. The outcome of this thesis is informed by existing research done on HIV medication and adherence[12].

1.4 Outline

Chapter 1 introduces the topic of medication adherence, its importance, and its effect on HIV/AIDS. It also unpacks the relationship between stigma and medication adherence. Chapter 2 features a literature review of the topics of medication adherence, HIV/AIDS stigma, and HIV/AIDS stigma in Ghana. In Chapter 3, a contextual review of existing medication adherence products is presented highlighting key features, strengths, and limitations. Chapter 4 describes my research methodology which draws upon techniques from Research Through Design and Health Design thinking. Chapter 5 reveals the user persona methods which I employed as part of my research process. In Chapter 6, I document the prototype-making process; the findings, and the results of the prototype I made. Chapter 7 is dedicated to using the design considerations framework I developed to evaluate my prototype against others on the market and the contributions of my work to the HIV/AIDS community. Chapter 8 highlights some of the learnings and insights from the prototype creation, the evaluation process, and the potential impact of the prototype on the HIV/AIDS community. Chapter 9 presents a conclusion of the outcomes and contributions of my research. Chapter 10 talks about the next steps of my research.

[12] Maria Yala, "The Big Disease with the Little Name: Retelling the Story of HIV and AIDS in an Evolving New Media Landscape" (MDES, OCAD University, 2020).

2 Literature Review

This chapter presents findings from the literature review I conducted that identify what medication adherence is, why it is an issue, and why research is needed to identify the barriers to adherence experienced by people living with HIV/AIDS (PLWHA). Finally, I discuss the history behind HIV stigma and how that is reflected in the Ghanaian context.

2.1 What is medication adherence?

Medication adherence is a serious healthcare concern around the world. The World Health Organization (WHO) defines medication adherence as the degree to which a patient follows medical instructions from a healthcare provider[13]. This can include taking medications (dosages), making lifestyle changes, and/or changing a diet[14].

2.2 Why medication non-adherence is an issue.

Adherence to treatment regimens is essential for successful treatment, and non-adherence to medication can have serious implications for both the individual and the healthcare provider. For the individual, medication non-adherence will reduce the patient's quality of life leading to higher mortality rates and worsening of the disease[15]. This leads to an increase in the use of medical resources such as nursing homes, hospital visits, and hospital admissions[16]. These consequences impact the ability of healthcare systems to achieve population health goals[17]. These can be seen in chronic diseases like diabetes. For example, a CODE-2 study (Cost of Diabetes in Europe – type 2) showed that the total cost of treating more than 10 million patients with type 2 diabetes in the countries studied was approximately US 29 billion, which represents an average of 5% of the total health care expenditure in each country[18].

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[13] Sabaté and World Health Organization, *Adherence to Long-Term Therapies*.

[14] Ibid.

[15] Sean D. Sullivan, "Noncompliance with Medication Regimens and Subsequent Hospitalization: A Literature Analysis and Cost of Hospitalization Estimate," *J Res Pharm Econ* 2 (1990): 19–33.

[16] Ibid.

[17] Sabaté and World Health Organization, *Adherence to Long-Term Therapies*, 11.

[18] Ibid.

It is clear from the literature that medication non-adherence is a problem. One that could have a harmful impact on a patient's health and hospital costs if not treated with care and consideration.

2.3 Medication non-adherence in HIV/AIDS

There is considerable evidence that many people with chronic illnesses, such as asthma, hypertension, diabetes, and HIV/AIDS, struggle to stick to their prescribed regimens[19]. In 2020, more than 37.7 million people were living with HIV/AIDS, with 73 percent of them receiving antiretroviral therapy (ART)[20]. This is below the target of 95-95-95 set out by the World Health Organization (WHO) to end the HIV/AIDS pandemic by 2030, where 95 percent of people living with HIV must be on an ART treatment plan[21]. Adherence is a critical aspect of treatment success.

Unlike other chronic diseases, the rapid reproduction and mutation rate of HIV necessitates extremely high levels of adherence (e.g., 95 percent) to achieve long-term viral load suppression[22]. Inadequate adherence can quickly lead to the development of resistance, increasing the risk for HIV transmission to others. Highly active antiretroviral therapy (HAART) is a robust and effective combination of antiretroviral medicines that have shown efficacy in lowering one's viral load and improving clinical outcomes[23]. However, the large number of doses combined with the complicated dosing requirements make adherence difficult[24]. Because adherence to HIV antiretroviral treatment is so important, good measures for promoting adherence are required.

There are some other factors however that might impact one's ability to adhere to their anti-retroviral therapy regimen (ART) such as sociodemographic factors (e.g., poorer adherence among older adolescents and those living in spaces with less privacy such as foster care or orphanages);

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[19] Ibid.

[20] Geneva: Joint United Nations Programme on HIV/AIDS, "UNAIDS Data 2021."

[21] UNAIDS, "AIDS by the Numbers 2015."

[22] David L. Paterson et al., "Adherence to Protease Inhibitor Therapy and Outcomes in Patients with HIV Infection," *Annals of Internal Medicine* 133, no. 1 (July 4, 2000): 21, https://doi.org/10.7326/0003-4819-133-1-200007040-00004.

[23] Sabaté and World Health Organization, *Adherence to Long-Term Therapies*.

[24] Ibid.

individual factors (e.g., forgetfulness); and treatment-related factors (e.g., high pill burden)[25]. Other challenges which are often overlooked such as stigma, (especially in boarding schools) can be a significant barrier to adherence, especially in Sub-Saharan Africa[26].

2.4 Understanding HIV/AIDS Stigma

Historically, a few diseases have been known not only for their significant contribution to mortality and morbidity worldwide but also for the social stigma they carry[27]. HIV/AIDS is one of those diseases.

Stigma is defined as an attribute or characteristic that is contrary to a norm of a 'social unit'[28]. A 'social unit' is an individual, or a group or community, considered as a discrete constituent of a society or larger group[29]. Stigma related to HIV/AIDS refers to derogatory attitudes, beliefs, and behaviors directed towards people living with the disease[30]. HIV-related stigma has a negative effect not only on the individual's social status, but it also impacts their familial relationships, economic relationships and has even created barriers to healthcare access, prevention, and treatment[31].

This resulting stigma is said to have had a negative impact on poor treatment adherence. For example, one study revealed that those with a high concern for HIV stigma were 3.3 times more

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[25] Sarah MacCarthy et al., "'How Am I Going to Live?': Exploring Barriers to ART Adherence among Adolescents and Young Adults Living with HIV in Uganda," *BMC Public Health* 18, no. 1 (October 4, 2018): 1158–1158, https://doi.org/10.1186/s12889-018-6048-7.

[26] Ammon, Mason, and Corkery, "Factors Impacting Antiretroviral Therapy Adherence among Human Immunodeficiency Virus–Positive Adolescents in Sub-Saharan Africa: A Systematic Review."

[27] KA Lawler, "Psychological-Aspects Of Serious Illness-Chronic Conditions, Fatal Diseases, And Clinical Care-Costa, Pt, Vandenbos, Gr," *Amer Psychological Association*, 1992.

[28] Jenev Caddell, "How to Cope With Stigma When You Have a Mental Illness."

[29] "SOCIAL UNIT | Meaning & Definition for UK English | Lexico.Com," Lexico Dictionaries | English, accessed March 25, 2022, https://www.lexico.com/definition/social_unit.

[30] Richard Parker and Peter Aggleton, "HIV and AIDS-Related Stigma and Discrimination: A Conceptual Framework and Implications for Action," *Social Science & Medicine* 57, no. 1 (2003): 13–24.

[31] Rintamaki et al., "The Role of Stigma Management in HIV Treatment Adherence."

likely to report nonadherence than were those with low concerns for HIV stigma[32]. The conventional way in which HIV patients resort to managing HIV stigma is through different forms of concealment[33]. The first concealment strategy is one that causes the individual to forego or delay their medication. Some individuals alter how they store their medication, for example, by throwing out key medication instructions and swapping out the original medicine container for another[34]. This is not ideal, as the individual may end up confusing medications and the wrong medicine could be ingested. For HIV medication to be effective, the medications must be taken on time and at their full dose capacity[35]. Missing a dose could prove detrimental to one's health.

Thinking through interventions to improve medication adherence for people living with HIV/AIDS (PLWHA), is not a one-size-fits-all solution. People living with HIV/AIDS (PLWHA) have their own concerns that impact their medication adherence. The current concealment strategies that HIV patients go through to conceal their status, run the risk of leading to important medical information being lost as well as ingesting mixed doses.

2.5 HIV Stigma in Ghana

HIV-induced stigma continues to be a global issue, particularly in low-income countries, posing a threat to the emotional well-being of persons living with HIV(PLHIV). In 2020, more than 20 million people in Sub-Saharan Africa (SSA) were living with HIV/AIDS [36]. In 2020, Ghana is estimated to have 350,000 people living with HIV [37]. Out of this number, 13,000 adults and children have died from AIDS[38]. Ghana has a 1.7% prevalence rate, with HIV prevention and treatment

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[32] Lance S Rintamaki et al., "Social Stigma Concerns and HIV Medication Adherence," *AIDS Patient Care & STDs* 20, no. 5 (2006): 359–68.

[33] Rintamaki et al., "The Role of Stigma Management in HIV Treatment Adherence."

[34] Ibid.

[35] Rintamaki et al., "The Role of Stigma Management in HIV Treatment Adherence."

[36] Joint United Nations Programme on HIV/AIDS (UNAIDS, *Report on the Global HIV/AIDS Epidemic.* (UNAIDS, 2002).

[37] UNAIDS, "Country: Ghana," UNAIDS, accessed December 5, 2021, https://www.unaids.org/en/regionscountries/countries/ghana.

[38] Ibid

initiatives in place to tackle the AIDS epidemic[39]. However, according to reports from the United Nations Integrated Regional Information Networks (IRIN) on Africa, the Ghanaian government's AIDS initiative is in jeopardy due to stigma and a failing health system.

In Ghana and many other countries in Sub-Saharan Africa, HIV transmission is predominantly transmitted through heterosexual intercourse[40]. In these nations, sexual immorality or immoral practices are seen as the main cause of HIV/AIDS, and infected people are blamed for contracting the disease[41]. In other cases, the infection is viewed as a divine punishment meted out to those who perpetrate sins such as prostitution, promiscuity, drug use, or homosexuality [42]. In Ghana, religion plays an important role in many people's lives, leading to the belief that a person should not engage in sexual activity until they are married [43]. For some, it is believed that individuals who contract HIV/AIDS through commercial sex work or promiscuity bring shame to their families. The cause of HIV/AIDS stigma in Ghana can be attributed to cultural beliefs; combined with the dread of HIV/AIDS (due to a misunderstanding of AIDS and its mortality)[44].

The fear of stigma can have negative effects on familial relationships, degraded social networks, loss of employment, and even act as a barrier to healthcare access. Fear of stigma at the community level can lead to refusal of voluntary counseling and testing (VCT), increased gender-based violence, and marginalization of high-risk people [45]. Community members may be hesitant to seek voluntary counseling and testing (VCT) because they are afraid of finding out they are HIV positive, as well as

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[39] Ibid.

[40] Chijioke I Ulasi et al., "HIV/AIDS-Related Stigma in Kumasi, Ghana," *Health & Place* 15, no. 1 (March 2009): 255–62, https://doi.org/10.1016/j.healthplace.2008.05.006.

[41] Ibid.

[42] Lauris C Kaldjian, James F Jekel, and Gerald Friedland, "End-of-Life Decisions in HIV-Positive Patients: The Role of Spiritual Beliefs," *Aids* 12, no. 1 (1998): 103–7.

[43] Awusabo-Asare, Kofi, Abane AM, and Kumi-Kyereme A., "Adolescent Sexual and Reproductive Health in Ghana: A Synthesis of Research Evidence," Occasional Report, 2004, http://www.guttmacher.org/pubs/or_no13.pdf.

[44] Ulasi et al., "HIV/AIDS-Related Stigma in Kumasi, Ghana."

[45] William L. Heyward et al., "Impact of HIV Counseling and Testing among Child-Bearing Women in Kinshasa, Zaïre:," *AIDS* 7, no. 12 (December 1993): 1633–37, https://doi.org/10.1097/00002030-199312000-00014.

the stigma and discrimination that may come with it. As a result, HIV-related stigma and prejudice may have a significant impact on the decision of people living with HIV/AIDS to disclose their status and the subsequent care, support, or treatment they get[46]. People who feel stigmatized or discriminated against have a higher risk of poor health, socio-psychological issues, and suicidal thoughts[47].

3 Contextual Review

As technological advancements continue to revolutionize health care, pharmacists and other clinicians are increasingly turning to digital solutions to help their patients stick to their medications. In this section, I share the results of a quick scan of the market for existing patient-focused medication adherence products. The solutions found were grouped into two categories. pill bottles/containers and wearable solutions.

3.1 Pill Bottles/Containers

There are a variety of products on the market that help individuals store and organize medication. The products that were looked at here are Pillsy, Vitality GlowCap by NantHealth, Aidia by AdhereTech, and PillDrill.

Pillsy, Aidia by AdhereTech and Vitality GlowCap are pill bottle solutions that have a built-in notification system to remind users when it is time to take their medication. The PillDrill has a line of products that supports different aspects of the medication-taking process. The main component is the PillDrill Hub, which has an in-built notification system for reminders, and an RFID scanner to track scanned dosages[48].

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[46] Linda Moneyham et al., "Experiences of Disclosure in Women Infected with HIV," *Health Care for Women International* 17, no. 3 (1996): 209–21.

[47] RL Sowell et al., "Barriers to Health-Seeking Behaviors for Women Infected with HIV.," *Nursingconnections* 9, no. 3 (1996): 5–17.

[48] PillDrill Inc, "PillDrill - Care That Connects™," accessed December 6, 2021, https://www.pilldrill.com.

All the products mentioned make use of both visual and auditory feedback on the device itself to alert users of dosages. The Pillsy bottle makes a beeping sound when it is time for medication, the Aidia by AdhereTech solution lights and chimes to alert the user when it is time for their next dose[49], the GlowCap lid flashes an orange light indicator and the PillDrill gives out audio-visual notifications when dosages are due, and the user waves their medication container (which has been affixed with a scanning tag) to record medication intake[50].

In addition to these notifications, Aidia, Pillsy, Vitality GlowCap, and PillDrill all allow customizable reminders and notifications for missed doses via app notification, text, or automated phone calls. Aidia even offers the assistance of a live agent specialist as well to support changes in dose schedule.

Finally, a common feature that is shared among these products is the ability to share medication intake data with family members or caregivers. They all collect, record patient data, and share this information with the patients' healthcare team and families.

3.2 Wearable Solutions

In one of the research studies[51], the author presents a wearable system for measuring patient medication adherence. This device measures adherence up to the point of determining if the medication has been ingested. This wearable is a pendant-style necklace that includes a piezoelectric sensor, a Radio Frequency (RF) board, and battery[52]. The piezoelectric sensor is used for sensing the mechanical stress resulting from skin motion during pill swallowing and generating voltage as a

[49] "AdhereTech," accessed March 28, 2022, https://www.adheretech.com/how-aidia-works/.

[50] Inc, "PillDrill - Care That Connects™."

[51] Haik Kalantarian et al., "Non-Invasive Detection of Medication Adherence Using a Digital Smart Necklace," in *2015 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops)* (2015 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops), St. Louis, MO: IEEE, 2015), 348–53, https://doi.org/10.1109/PERCOMW.2015.7134061.

[52] Ibid.

response[53]. Acquired data is sent via Bluetooth to a mobile phone that runs classification algorithms which are analyzed further[54].

Major challenges associated with this approach pertain to user comfort and social acceptance as the necklace needs to be worn by the patient and must be fastened and placed in contact with the skin during dose swallowing[55].

Another example for measuring medication adherence is neck wearables which use acoustic sensors. This method has been used in food intake tracking applications[56]. Although more research is needed, this method has the potential to be used in medication monitoring. Acoustic-based techniques, in general, gather acoustic data resulting from swallowing or ingestion activity with a microphone placed near the neck[57]. So far, only one prototype exists developed by Wu et al[58]. The microphone and the flex sensor are to be employed for sensing throat movement and chewing sound associated with medication swallowing activity[59]. As a result, the authors included an RFID reader to provide another layer of medication adherence verification by monitoring pills with ingestible biosensors as they pass down the throat[60]. However, the current version of the study lacks any

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[53] Ibid.

[54] Ibid.

[55] H. Kalantarian, N. Alshurafa, and M. Sarrafzadeh, "A Survey of Diet Monitoring Technology," *IEEE Pervasive Computing* 16, no. 1 (March 2017): 57–65, https://doi.org/10.1109/MPRV.2017.1.

[56] Tri Vu et al., "Wearable Food Intake Monitoring Technologies: A Comprehensive Review," *Computers* 6, no. 1 (2017), https://doi.org/10.3390/computers6010004.

[57] Murtadha Aldeer, Mehdi Javanmard, and Richard P. Martin, "A Review of Medication Adherence Monitoring Technologies," *Applied System Innovation* 1, no. 2 (2018), https://doi.org/10.3390/asi1020014.

[58] Xiaolong Wu, Young Mi Choi, and Maysam Ghovanloo, "Design and Fabricate Neckwear to Improve the Elderly Patients' Medical Compliance," in *Human Aspects of IT for the Aged Population. Design for Everyday Life*, ed. Jia Zhou and Gavriel Salvendy, vol. 9194, Lecture Notes in Computer Science (Cham: Springer International Publishing, 2015), 222–34, https://doi.org/10.1007/978-3-319-20913-5_21.

[59] Ibid.

[60] Ibid.

validation trials, making it difficult to draw conclusions about the approach's performance, social acceptance, and comfort[61].

The strengths and limitations of the pills/containers against the medication adherence wearable sensors are outlined in Appendix A.

From the contextual review of the pill containers and the medication adherence wearable sensors, I have learned that the most common features crucial for such devices are the need for an in-built notification system and a form of alert feedback. Additionally, what I have noticed with all these devices is how they are designed as one-size-fits-all solutions for everyone, failing to consider specific barriers to adherence that might affect certain diseases more than others. I have learned from my research that it is important to have a form of notification and feedback that is not immediately noticed by others to address concerns about the stigma raised by people living with HIV/AIDS (PLWHA). These wearable solutions described here only detect if a pill is taken but are not storage devices. The wearable prototype I will be creating will be both a wearable storage and monitoring device.

4 Methodology

A design approach is used to address the research question defined earlier in the thesis. Research through design (RtD) and health design thinking have been defined. These topics have been described as they relate to the research being conducted in this study and why they were appropriate methods for my research.

4.1 Research through design (RtD)

Research through design (RtD) is a term that is used in Interaction Design and Human-Computer Interaction (HCI) which refers to an "informal methodological approach that is a foundational concept for practice-based inquiry with the aim of generating transferable knowledge[62]. There are

[61] Ibid.

[62] Abigail C. Durrant et al., "Research Through Design: Twenty-First Century Makers and Materialities," *Design Issues* 33, no. 3 (July 1, 2017): 3–10, https://doi.org/10.1162/DESI_a_00447.

different definitions for *research through design* as it is a term that is constantly evolving. At the heart of research employed in RtD is object creation. This recognizes the design process as part of research that produces different forms of knowledge. In this design approach, the designer's output usually in the form of prototypes is what contributes to the knowledge outcome. These prototypes are constantly undergoing an iterative, trial and error process of experimentation[63]. This works by having a designer create a sequence of prototypes in steps, with each information gained informing the next decision and at the same time addressing different parts of the research question.

The importance of this methodology in my research is that it allows for rapid prototyping and experimentation. Being able to test different sensors and electronics to find what best works for my research has allowed me to select electronics that work best for both the design and function of my prototype.

4.2 Health Design Thinking

Health design thinking helps deal with the question of how we might achieve better health through improved services, products, interactions, and education[64]. It is an approach where creative ideas and solutions are generated to enhance human health in the context of medicine[65]. The health design thinking process consists of core principles and methods. Design Thinking as a methodology employs two main principles when approaching problems[66]. First, design thinking must be human-centered. To be human-centered means to put the needs and desires of people above a business or an artistic idea[67]. The core methods of human-centered design involve observation, conversation, research, and collaboration[68]. Second, design thinking requires a creative mindset preferring an open-ended approach to problem-solving rather than a linear method with a predetermined

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[63] Owen B Chapman and Kim Sawchuk, "Creation: Intervention, Analysis and" Family Resemblances"," *Canadian Journal of Communication* 37, no. 1 (2012).

[64] BON. KU, *HEALTH DESIGN THINKING : Creating Products and Services for Better Health.* ([S.l.]: MIT PRESS, 2022).

[65] Ibid.

[66] Ibid.

[67] Ibid.

[68] Ibid.

outcome[69]. Asking deeper questions, visualizing ideas, creating tangible prototypes, and storyboarding are all part of the creative process[70]. There are three main phases of the health design thinking process: observation, imagining, and making.

Out of the three main phases of the human-centered design process, there are two which I employ in my project - imagining and making. In the imaging stage, one must come up with multiple ideas, sort them into groups, seek relationships and analogies, and decide how to move forward. Here we can see a mix of human-centered research and creative thinking[71].
The final step is to make. Making is otherwise known as the action stage. This is where prototypes, storyboards, and role-playing as creative methods are employed as tools for communicating with users and stakeholders[72].

I was drawn to this approach, due to its application in healthcare as well as the principles and methods utilized within this methodology. During the research phase, I set out to first understand the needs and desires of people living with HIV/AIDS (PLWHA) when navigating anti-retroviral therapy medication regimens (ART). I looked up existing research on stigma management and its effect on adherence. The results from my research helped me understand the different concealment strategies people living with HIV/AIDS (PLWHA) employ to avoid stigma when adhering to their medication. The fact that concealment strategies were being deployed tells me that the discreteness of the medication is a problem. This informed me that people living with HIV/AIDS require solutions that are discrete and portable.

After the research phase, I employ the other phases of the design process, imagining and making. To do this I first created personas of my intended user group, then I developed sketches of what I wanted the prototype to look like, developed a design considerations document, and then moved into the prototyping phase to test how the functionality of the envisioned design will work out in practicality.

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[69] Ibid.

[70] Ibid.

[71] Ibid.

[72] Ibid.

5 Personas as Research Methods

Personas are a technique used during the research phase in human-centered design to understand user needs[73]. They depict a user group's traits and objectives, such as common habits, abilities, attitudes, restrictions, and constraints[31]. Personas also gather information about the environment in which the user group lives and works within. The goal of personas is to express user needs so that functional and experience guidelines may be developed to guide the creation of the intended solution.

Unfamiliar with the needs and wants of people living with HIV/AIDS (PLWHA), I decided to create personas to help guide and inform the design of the Pill Assist prototype. Due to the fact I was unable to recruit people within the HIV/AIDS community to interview, these personas created were based on literature reviews and existing research studies on the role of stigma in HIV/AIDS treatment adherence[74]. I gathered data on past research studies on the role of stigma in HIV/AIDS treatment adherence in different areas in Ghana.

This set of two personas was created to inform my designs for possible improvements to medication adherence solutions catered to people living with HIV/AIDS who face stigma. During my literature review, I discovered that people living with HIV/AIDS (PLWHA) who are most likely to struggle with medication adherence can be classified into two main categories; the newly diagnosed and those with complex medication regimens. A person who is newly diagnosed with HIV/AIDS is concerned about how they can keep their status private when managing their medication. This is often due to the fear of being stigmatized by people around them. A person with a complex anti-retroviral medication regimen (ART) is more concerned about how they can keep up with their medication anywhere, at any time, and can be taken without being noticed by others.

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[73] "What Are Personas?," The Interaction Design Foundation, accessed March 25, 2022, https://www.interaction-design.org/literature/topics/personas.

[74] Abdul Alhassan Mumin et al., "Internalised and Social Experiences of HIV-Induced Stigma and Discrimination in Urban Ghana," *Global Social Welfare* 5, no. 2 (2018): 83–93.

Persona 1: Newly diagnosed person living with HIV/AIDS (PLWHA).

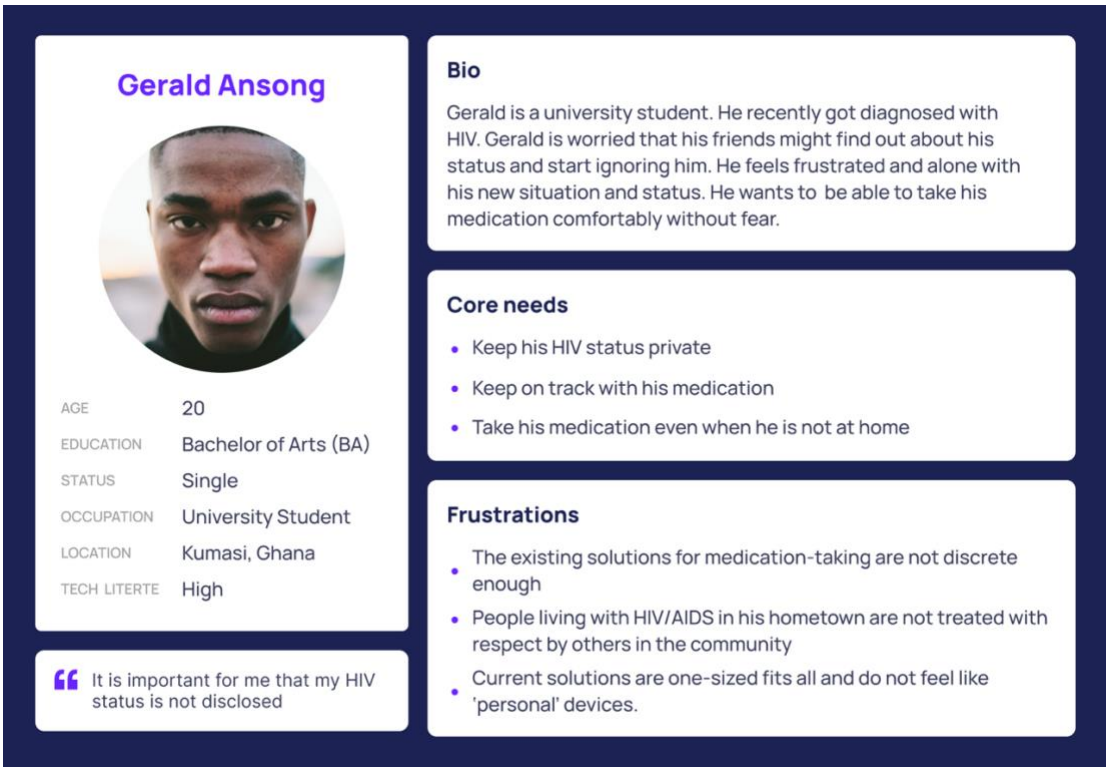

Figure 1 - A persona of Gerald, a newly diagnosed person living with HIV/AIDS

Persona 2: A person living with HIV/AIDS on a complex anti-retroviral regimen (ART)

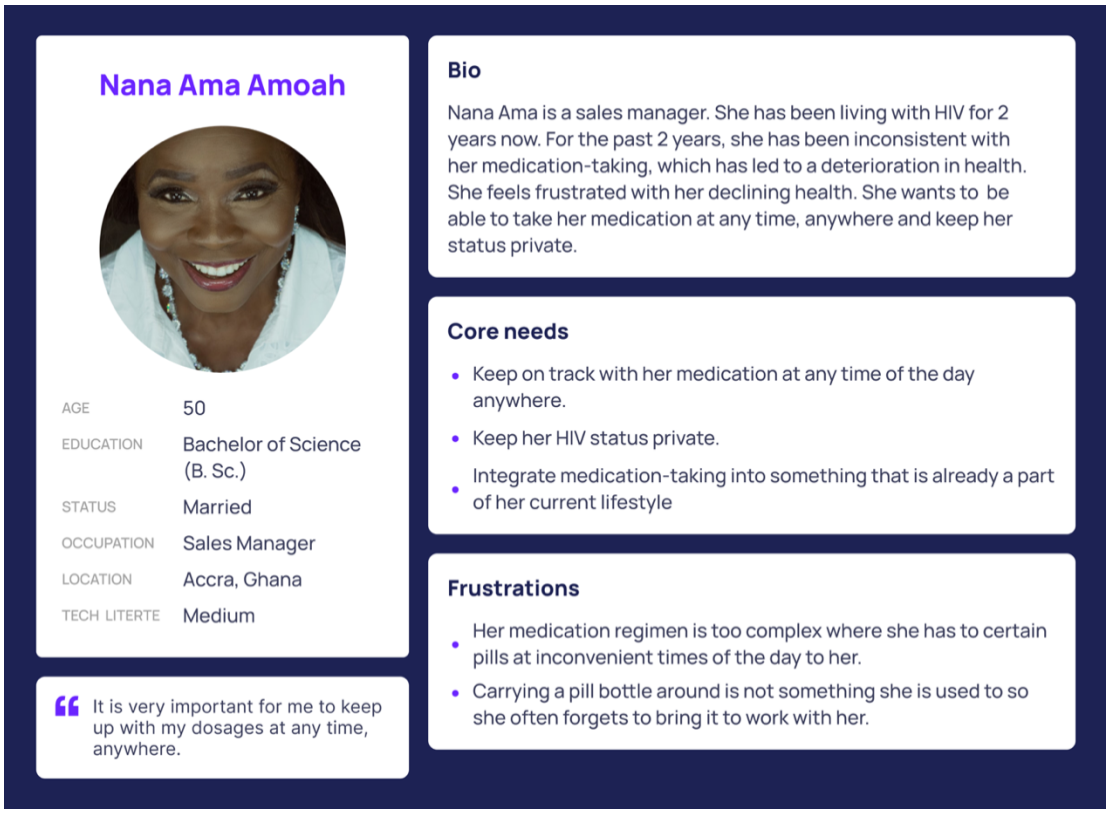

Figure 2 - A persona of Nana Ama, a person living with HIV/AIDS on a complex anti-retroviral regimen (ART)

Creating these two personas helped me narrow down to a specific category of people within the scope of people living with HIV/AIDS (PLWHA) and focus the prototype on addressing the needs of two different archetypes of people living with HIV/AIDS (PLWHA).

6 "Pill Assist" Prototype

This chapter details the creation of one prototype built using contemporary digital media technologies such as electronics. In this chapter, my process is outlined, from performing different technology explorations and visual design wireframe mockups to the final creation of the prototype using fabric textiles.

6.1 Concept

The Pill Assist prototype is a wearable device that takes a traditional wallet and transforms it into a dual-purpose medication storage and reminder system. The concept has been visualized as an interactive device consisting of a Liquid Crystal Display (LCD), three buttons for interactions, a vibration motor for tactile feedback, an Arduino microcontroller, a real-time clock module, and a battery. This prototype will help remind and track/monitor dosage intake.

6.2 Electronic Components

Presented below are the different components that make up the prototype and their functions.

Microcontroller

This is the main component of the prototype and is designed to store and control the functions present in the prototype. It must have both enough Read-Only Memory (ROM) to store the software along with saving the different alarm slots and Random Access Memory (RAM) to process the running program. A microcontroller suitable for rapid prototyping is chosen for this phase.

Vibration Motor

The vibration motor acts as a reminder system to alert users of an upcoming dosage. This is to maintain discreteness for the medication taker.

Infrared Proximity Sensor (IR)

The infrared proximity sensor is fixed inside the Pill Assist and once the wallet is opened, the device detects that the pill has been taken.

Liquid Crystal Display (LCD)

The Liquid Crystal Display (LCD) contributes to a user-friendly interface and is crucial for navigating the prototype's different modes to set an alarm. The display must have high contrast and clear text to account for a wide range of people who might use it.

Buttons

Next to the LCD are three buttons, each tasked with performing different interactions. This allows for a simpler setup without the need for too many buttons to perform different functions. A *mode* button is designed to cycle back and forth between the clock display home screen and the alarm mode. An *OK/Enter* button is used to confirm a choice and advance through a mode option, while a *toggle* button is used to change the different time values in the alarm mode and the month, day, year, and time in the Set Date/Time mode.

Real-Time Clock (RTC) Module

Keeping track of time accurately to schedule the alarm is one of the most important tasks for the prototype to achieve. The RTC is an integrated circuit that is used to keep track of time. It makes use of a backup battery to maintain the accuracy of time even when the power source is switched off.

6.3 How does Pill Assist Work?

When the user gets their medication from the pharmacy, they fill the pill compartments in the Pill Assist device with enough dosage to potentially cover six days in the week, depending on pill size. When the user turns the device on, they are taken to the home screen which displays the date and time of the day. There are three different modes to toggle on the device. Clock with Date Display, Alarm Slot, and Set Date/Time. To set an alarm, one must first toggle to the Alarm Slot mode, from there they are guided to pick a time slot from a selection of five different time slots. Once a slot is selected, the user can select his/her preferred time for the alarm to go off and is prompted to activate the alarm on/off. This allows the user the flexibility to set different alarms but choose which ones to enable or disable.

Once the alarm goes off, the user must either pick a pill from the pill container or press the *mode* button for the alarm to go off. The alarm goes off once the infrared (IR) proximity sensor detects that the pill has been picked by the user or when the *mode* button is pressed.

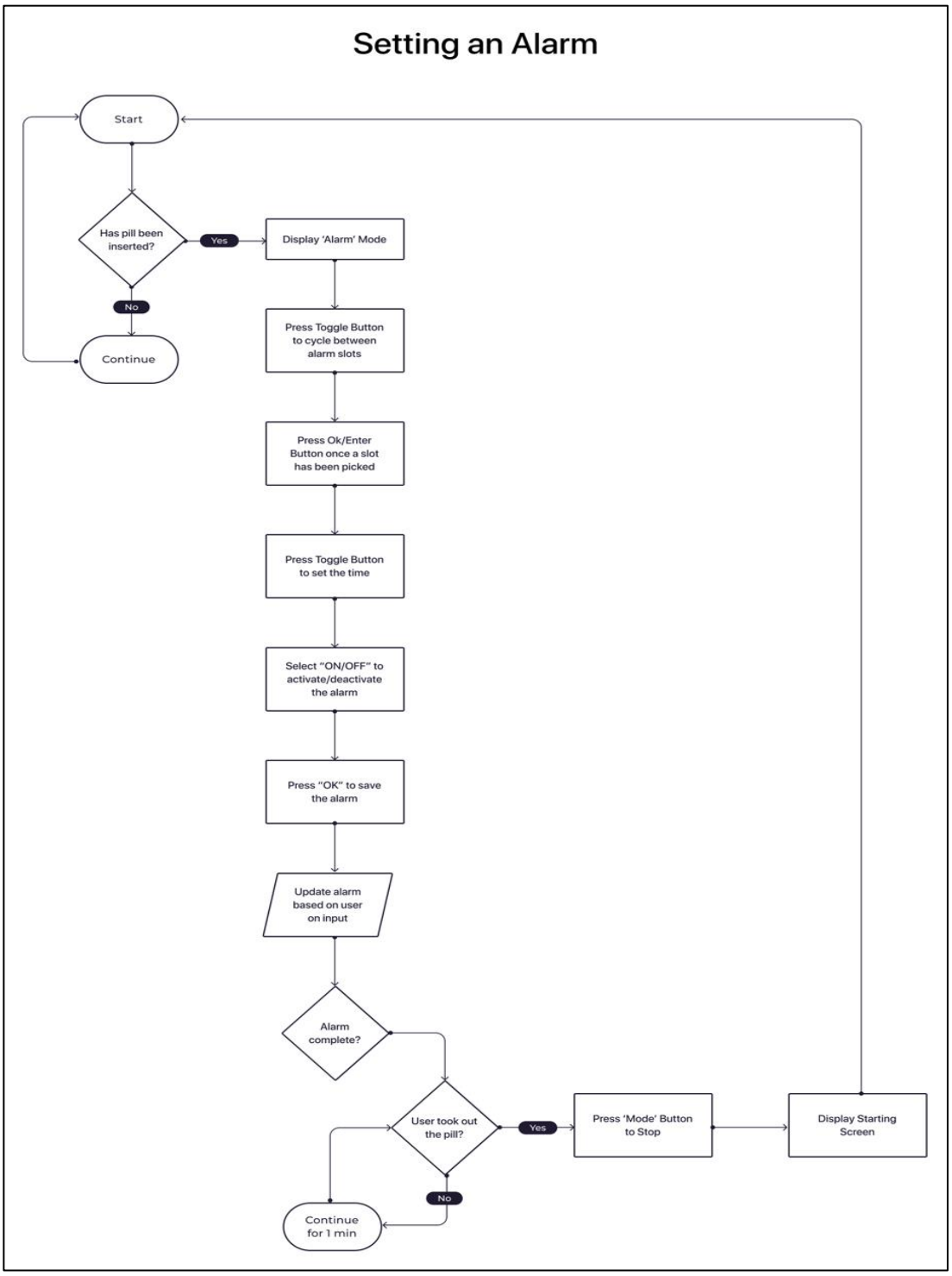

Figure 3- A flowchart showing how an alarm is set on the Pill Assist prototype

6.4 Electronics Overview

As part of my development, I tried different reminder systems such as a timer and feedback systems such as LEDs and buzzers but arrived at the current design which best supports my design priorities and is reviewed in detail in this section. The early electronic prototypes can be seen in Appendix C.

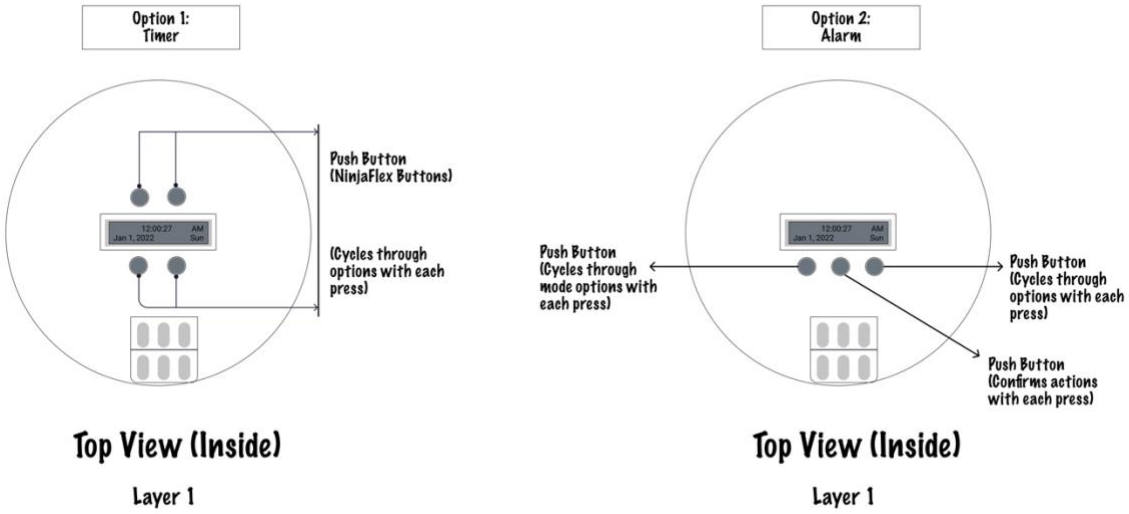

Figure 4 – Timer vs Alarm Function

Reminder System

The reminder system was tested using a timer function and an alarm function. After testing programming with the timer function and the alarm function, the alarm function proved to be the most suitable as a reminder system for medication-taking. With the timer function, users would have to set the timer every time before and after they had taken a dose. This will not make the process easy especially if they had to do that in a public space. With the alarm function, however, users can set five different alarms for the different dosages they have to take. This is more convenient for them because they do not have to worry about forgetting to set the alarm and can go about their daily activities knowing that their dosage reminders have been set.

Feedback System

The feedback system was testing out the tactile feedback using a vibrating motor. The vibrating motor produces a subtle vibrating motion that can be felt by the user when the device is placed on

their body. A big advantage of this method over the other forms of feedback is that the vibration is not sensed easily by others not taking the medication. I decided to move forward with the vibrating motor due to its discreteness. This is something I had learned during the contextual review and tested it out to validate my earlier hypotheses.

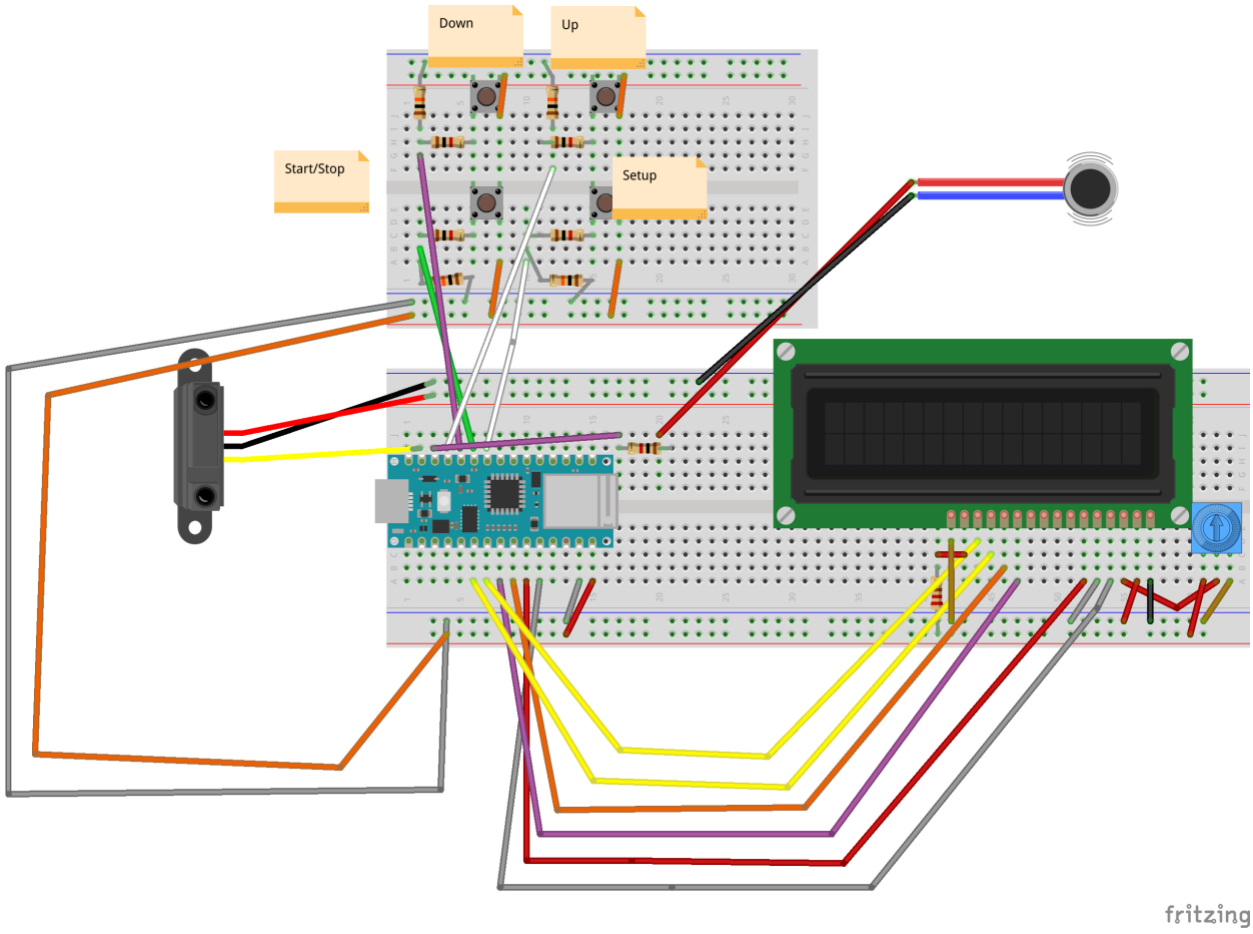

Figure 5 - Circuit Diagram using a Vibrating Motor for tactile feedback

6.5 Container Design Explorations

A total of 3 design form factors for pillbox containers were created in Figma, a digital design and prototyping software. The main priorities were that the design should be discrete, portable, and intuitive.

- Discrete: Does not look like a medication-storing device.
- Portable: Easy to carry around.
- Intuitive: Easy to be operated by the user.

In determining the size of the pill compartments in all the designs, the HIV anti-retroviral regimen drug chart was referenced[75]. From the chart, the average number of times a day a pill had to be taken for a regimen was 2 times[76]. There were few pill regimens where people were required to take at least six pills a day[77]. In the following designs, space was created to house at least six pills, depending on the pill size.

6.5.1 Design 1: Wallet

The first design explored the wallet and how that could be transformed into a storage container for pills. The bi-fold wallet style was the primary inspiration that was looked at. The wallet is an essential item that most people carry on them when leaving the house, so the idea behind this is that it is discrete and will not be an out-of-place item to have.

The front of the wallet will have the LCD screen with the welcome message displayed on it and right below it the three buttons for interacting with the LCD. To maintain the discreteness of the LCD screen, it will be covered up by a nametag which will either slide/flip over to reveal the LCD when the user wants to interact with it. The buttons will be covered up as well with pieces of material while displaying some designs which make it look like it is a part of the wallet.

Figure 6 - An illustration of the outside of the Pill Wallet.

[75] "HIV Drug Chart," POZ, accessed March 31, 2022, https://www.poz.com/drug_charts/hiv-drug-chart.

[76] Ibid.

[77] Ibid.

The inside of the wallet will have different compartments for keeping cards and below it is the different electronics that power up the functionality of the LCD. A special compartment will be created to hide the electronics visually. On the right side of the wallet, there are additional card compartments and below it a compartment to keep the pills.

To include an added layer of personalization, the user is given the option to attach any sticker of their choice to this device. In the example below, the Ghana flag is used to represent one option a user can take for their sticker choice.

Dimensions of Pill Wallet
Width (Opened): 8 inches
Width (Closed): 4 inches
Height: 3 inches
Thickness: ½ inch

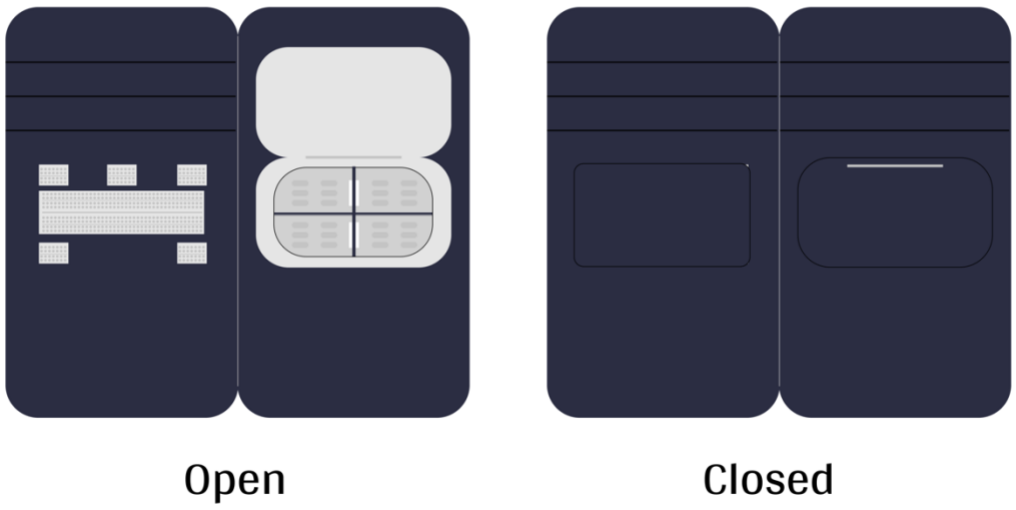

Figure 7 - An illustration of the inside of the Pill Wallet.

6.5.2 Design 2: Pill Chain

The second design is based on the inspiration of the Memo by Yanko Design and the Apple Air pods case. The Memo is a portable Pillbox for Alzheimer's patients to remind them when and how

many pills to take, thanks to the ingenious use of LEDs[78]. The different medications are divided into different color-coded compartments. The LED System will glow to remind the patient to take his/her pills at the right time[31]. I decided to explore the idea of using different compartments for different types of pills and to use the Apple Airpods case for the shape and size of the prototype.

Like the previous design, the outside of the pill container will have the LCD screen with the welcome message displayed on it, and right beside it the three buttons for interacting with the LCD. It will also be covered up by a nametag which will either slide/flip over to reveal the LCD when the user wants to interact with it. The different pillbox compartments are color-coded red, gold, and green to represent different types of pills a user may take. They each have a small lid to allow for the opening of each container.

Figure 8 - An illustration of the outside of Pill Chain

The inside of the main compartments is each filled with four small pill containers each with a lid containing proximity sensors to detect opening and closing. Each pill container should be able to hold more than one pill and will have a haptic motor for vibrating feedback once the alarm goes off.

[78] "Pill Box for Alzheimer Patients - Yanko Design," February 21, 2012, https://www.yankodesign.com/2012/02/21/pill-box-for-alzheimer-patients/.

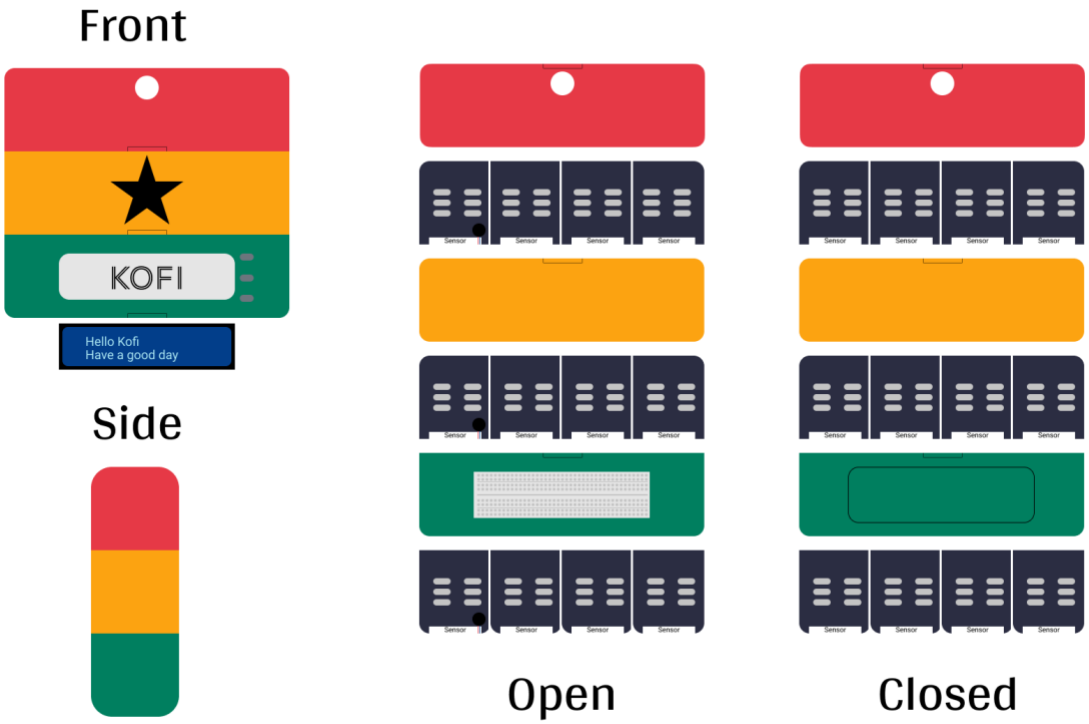

Figure 9 - An illustration of the inside of the Pill Chain

For an added layer of personalization, the entire casing of the pill container is designed in the colors of the Ghana flag. The color-coding of the container will be entirely customizable by the user at the time it is received.

Dimensions of Pill Chain

Height: 2.11 inches

Width: 1.74 inches

Depth: 0.84 inch

Weight: 1.41 ounces

6.5.3 Design 3: Pill Keychain

The third design is modeled after a keychain that the user can hang anywhere, from their clothes to a bag. A keychain is an essential item that most people use to hold their keys and carry with them when they are going out. The front of the keychain when closed will have some designs on the cover and just appear to look like a normal keychain. Once the flap is open, the LCD is fixed onto the

cover and once again concealed with the help of a nametag which helps to keep it discrete. The figure below shows what the outside will look like when it is closed and when it is open.

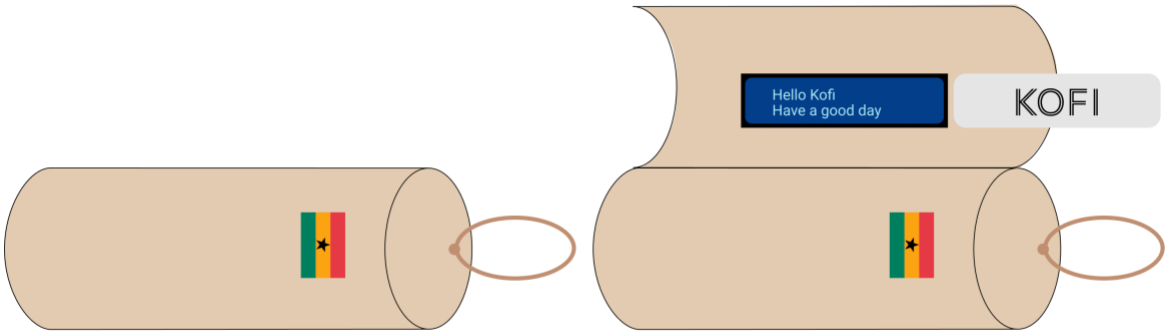

Figure 10 - An illustration of the outside of Pill Assist

The inside of the keychain is divided into two layers, the compartments layer, and the electronics layer. The electronics layer is where all the electronics and sensors will be housed. The buttons for interactions will also be located on this layer as well. The compartments layer will contain six pills compartments which can each hold approximately six pills. The two layers will be joined together and will have a cover to conceal both layers. The figure below shows what the two layers look like.

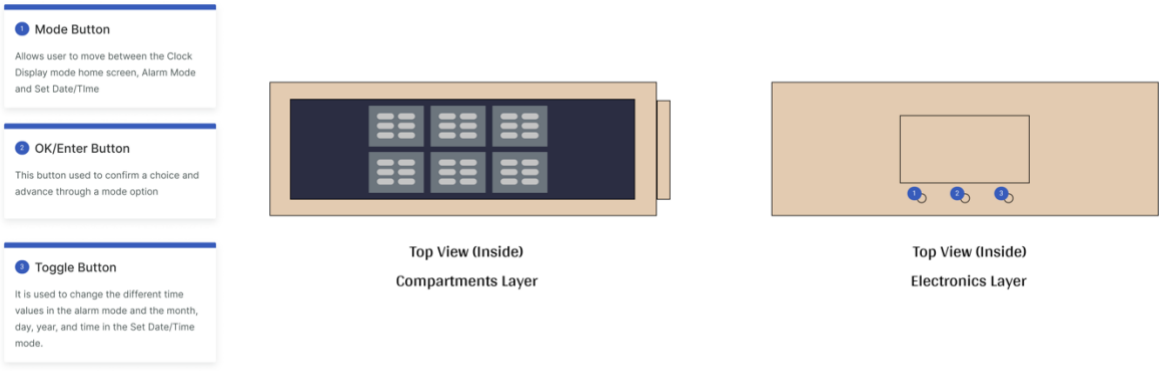

Figure 11 - An illustration of the inside of the Pill Assist

According to my assessment, all three designs successfully met the design criteria set out of being portable, discrete, and intuitive. However, the Pill Wallet was the selected design due to being the simplest to carry out because of the electronics and sensors I chose. Currently, with the parts I have acquired an LCD, real-time clock module, infrared proximity sensor, and some buttons, I was limited to designing a form factor that fits around the LCD dimensions. The Pill Chain, even though small would have been too complicated to connect the electronics I have together, the Pill Wallet offered the ideal balance between size and ease of circuit connection.

6.6 Results and Outcome

The final prototype outcome was a wallet design. This prototype includes an LCD screen for displaying the alarm as well as three buttons to navigate through the interface. On the inside, there are four slots for pill storage.

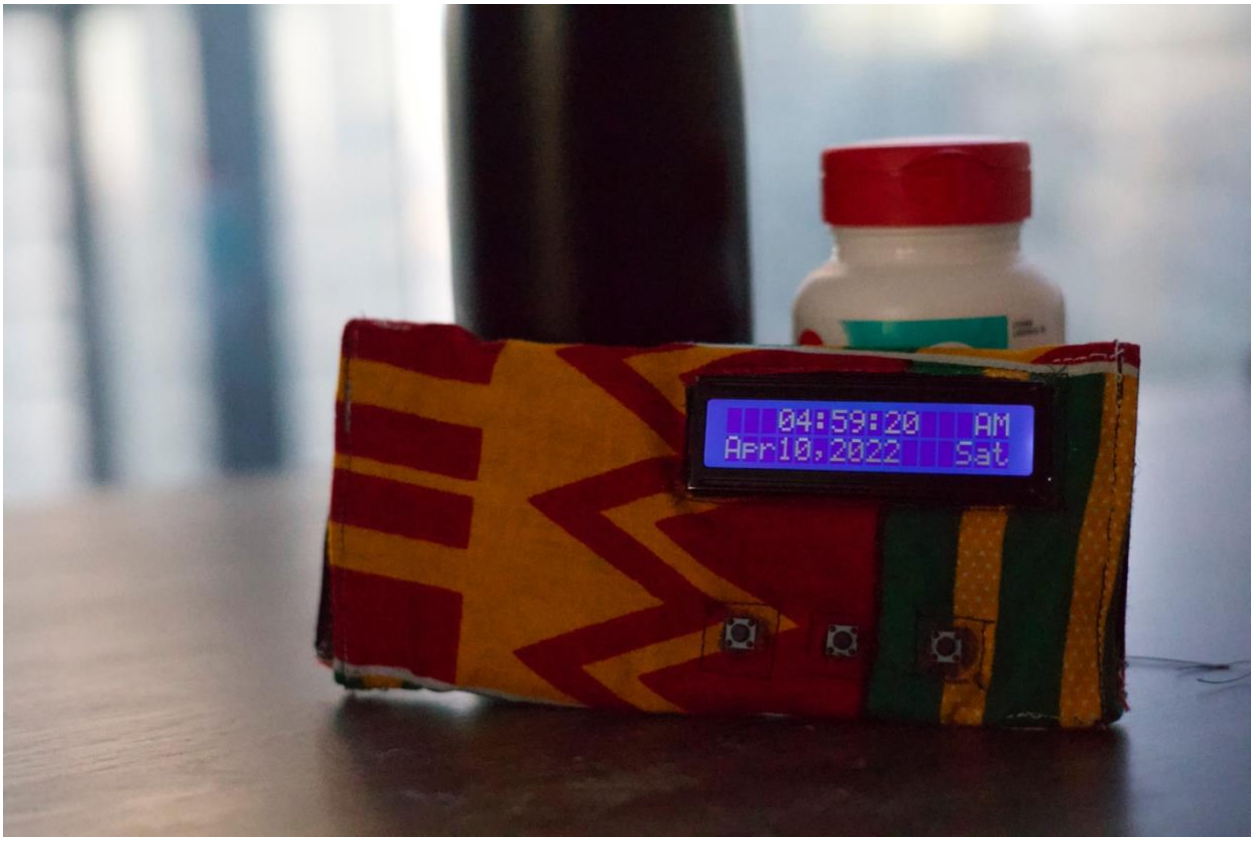

Figure 12 - A picture showing the display screen of the Pill Assist Wallet

Figure 13- A picture showing the Pill Assist Wallet alongside some example Vitamin pills

7 Analysis

The following chapter is broken down into two sections. The first section (7.1) describes the design considerations to evaluate the effectiveness of Pill Assist against other similar products in the market. The second section (7.2) shows a table evaluating the prototype against the different design considerations.

7.1 Design Considerations

To evaluate the effectiveness of the prototype in answering the research question, the following design considerations have been developed. These design considerations are based on a framework that referenced seven studies on the role of human factors in wearables[79]. I adapted the "Wearables

[79] Leire Francés-Morcillo et al., "Wearable Design Requirements Identification and Evaluation," *Sensors* 20, no. 9 (May 2, 2020): 2599, https://doi.org/10.3390/s20092599.

Design Requirements" framework for evaluating design requirements by modifying the design requirements based on usability, aesthetics, and privacy[80]. Usability requirements were considered in the functions of Reminder, Refill, and Medication storage, Aesthetics requirements were considered under the General, Integration, and Social factors, and Privacy was also considered in the Reminder and Medication storage factors.

These considerations were selected because they are most relevant to my target users of people living with HIV/AIDS. The referenced framework can be seen in Appendix B. These design considerations are intended to support those working on developing or evaluating a tool to aid in improving low medication adherence rates due to stigma for people living with HIV/AIDS (PLWHA). These considerations are grouped into two categories: functional guidelines and experiential guidelines. Functional guidelines are the components that need to be integrated into the prototype for it to be useful. Experiential guidelines take into consideration the users' different needs and behaviors that impact their use of medication. The figure below shows the different guidelines and the key topic considerations in each.

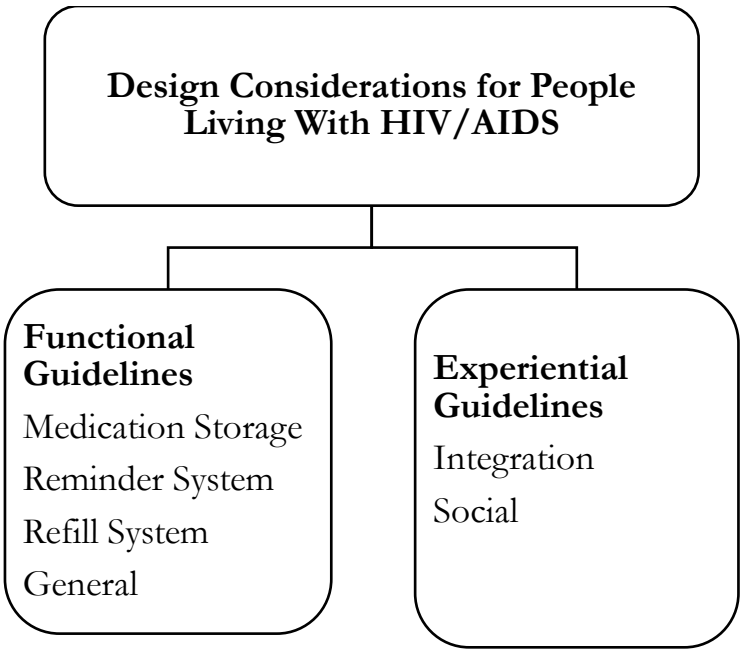

Figure 14 - The two guidelines identified as design considerations and their key topics

[80] Ibid.

7.1.1 Functional guidelines

Functional guidelines will help determine what needs to be included in a device that helps people adhere to their medication. These include a way for people to carry the required amount of medication; a reminder or notification which allows them to know when medication should be taken; a way of integrating the device with objects they use daily; a method for them to easily refill their device; as well as general needs such as having something that is simple to use and affordable. See the figure below for an illustration of the key functional guidelines and the factors described in each.

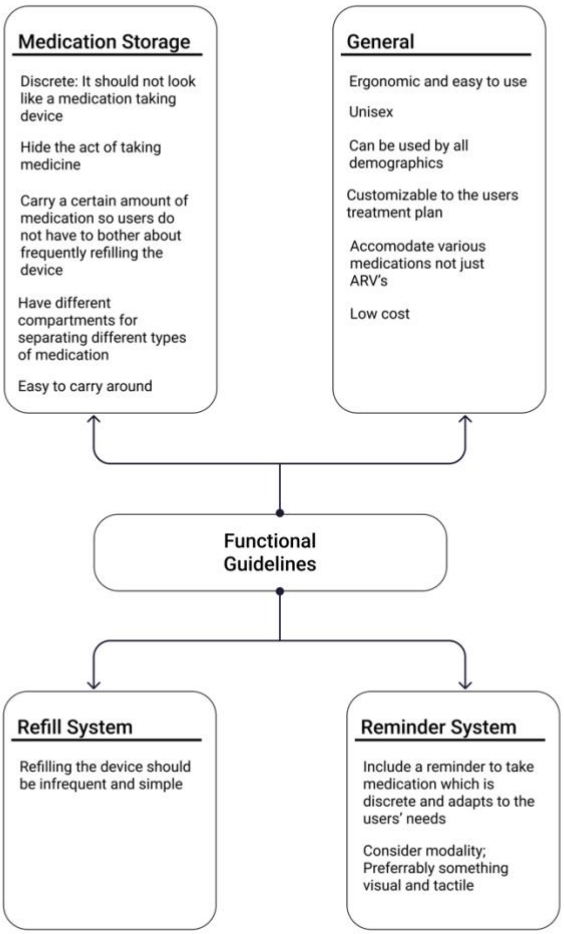

Figure 15 - An outline of the functional guidelines and the key factors identified in each

7.1.1.1 Medication Storage

The key things that need to be considered when designing for carrying medication include:

- The medication should be easy to carry around
- The device must be integrated into something that the user will typically carry with them every time they leave the house, for example, a phone or a wallet. This will make it easy for them to not forget their medication while keeping their medication discrete.
- In addition, it is important for the device to carry multiple days' worth of pills to reduce the burden of refills by the user. Storage spaces should store at least three to seven days' worth of pills.
- To help with the stigma, the device which carries the medication should not look like a traditional pill bottle
- The device needs to be able to accommodate different types of medication no matter the size.

7.1.1.2 Reminder System

The contextual review highlights the importance of having a reminder system to try to improve adherence. This was seen in many of the medication adherence products on the market. Pillsy, Vitality GlowCap by NantHealth (2018), Aidia by AdhereTech (2018) and PillDrill (2018) are some examples that have a reminder system.

The key considerations identified for the reminder system were that:

- It had to be discrete, reliable, and difficult to ignore. The individual taking the medication should be the only one who notices the reminder or is aware of what it means.
- For discretion, the modality of the notification is an important factor to consider. In terms of the alarm's modality, devices should include some form of tactile/visual. Auditory feedback is not a discrete enough mechanism.

7.1.1.3 Refill System

It is important to consider how an individual will be refilling the device used. Here are some things to think about:

- Devices should be quick and easy to fill but should not need to be refilled every day.

- There should be a reminder to refill the device

7.1.1.4 General

Here are some general guidelines which are good to consider in the overall design of the device:

- The device needs to be easy to use, ergonomic, and unisex.
- The device should easily be customizable for any medication regimen
- The device should be low-cost and easily affordable

7.1.2 Experiential guidelines

Experiential needs also need to be considered when designing devices to improve adherence. These include integrating the device into the users' existing lifestyle and daily routine; as well as social factors which may impact their adherence, such as stigma. See the figure below for a visual of the key experiential guidelines and the factors described in each.

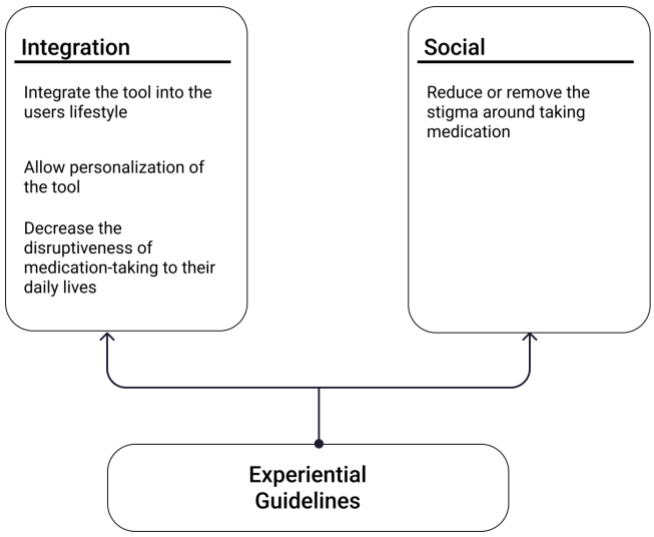

Figure 16 - An outline of the experiential guidelines and the key factors identified in each

7.1.3 Integration

Here are some topics to think about when deciding how to integrate solutions into users' daily lives:

- Integrate the tool into the user's lifestyle. Being able to integrate the device into items that people already carry with them.
- Personalization of the device is an important factor to consider.
- Decrease the disruptiveness of medication-taking to their daily lives

7.1.4 Social

In the literature reviews, social stigma has been described as a barrier to adherence. Stigma can lead to users hiding their medication dosage, causing them to miss or delay their doses. Therefore, the design of the device needs to reduce or remove the stigma around taking medication

7.2 Evaluation Process

This evaluation process looks at the proposed design for Pill Assist against five existing medication adherence products on the market. These products are evaluated based on the functional guidelines and experiential guidelines outlined in the previous chapter. The table below shows the design considerations in which Pill Assist does better than its competitors. It is important to note that none of the devices are true comparators because only Pill Assist is a wearable device that combines storage with a medication reminder.

*Note: Pill Assist is my thesis prototype.

Features	Pill Assist (Prototype Exploration)	GlowCap	Pillsy	Aidia (Adheretech)	PillDrill	Medminder (JON)
It should not look like a medication-taking device. Looks like an everyday object	Yes	No	No	No	No	No
Should be flexible to only carry the medication you need at a time	Yes	No	No	No	No	No
Should be discrete so that only the individual notices	Yes	No	No	No	No	No
Should be personalizable; e.g. Decorated	Yes	No	No	No	No	No

Table 1- Comparison of Pill Assist prototype design against five other products on the market using the design considerations framework

8 Discussion

8.1 Prototype Learnings

The development of this prototype involved two different stages: technology exploration and visual design exploration. The technology exploration provided valuable insight into testing the efficacy of these electronic components including notification methods. I learned that it is quite challenging to make an interactive pillbox that is small and discrete due to the size of the electronic components. The design exploration helped me think critically about the specific demographic I was designing for by taking into consideration a few things specific to the Ghanaian context. For instance, I had to think about the everyday items that people from Ghana were likely to carry around.

8.2 Evaluation Process

From the evaluation process, I demonstrate that a potential advantage that the proposed Pill Assist prototype design has over the other products on the market is its ability to be integrated into an everyday item that the user will typically carry around and is already a part of their daily workflow. Another advantage is the personalization aspect of the intended prototype design. Most of the existing devices that support medication adherence are mass-produced which at times can make the device feel less personal. The intention of allowing the users of the device to customize their personal device is to allow them to feel more connected with their device. This evaluation, however, does not suggest the intended prototype design proposed in my research is superior to its predecessors. While other solutions presented may offer a stronger case in terms of overall device functionality and interconnectivity, the strength of the proposed Pill Assist prototype design is that it is a wearable device that combines storage with a medication reminder system - something none of the other devices currently do. The prototype designs I created are also meant to encourage a different way of thinking about pillbox designs.

The final prototype outcome of the Pill Assist wallet helps meet the parameters of the design considerations I set both in form and function in the following ways. The overall look and feel of the Pill Assist look like a regular wallet and is made from fabric material which can be found on some real wallet designs. The slots designed inside the wallet for pill storage are discrete and can

store multiple pills. The fabric material used is meant to be customizable depending on the user's preferences.

8.3 Potential Impact On People Living with HIV/AIDS (PLWHA) in Ghana

As I belong to the Ghanaian international community, I hope this intended prototype design will help encourage people within the HIV/AIDS community in Ghana to lend their voices towards the creation of devices that cater to their needs. From the literature review, we have learned that stigma is still very much an issue in Ghana, affecting the quality of life and most importantly medication adherence. I learned that some people go to any length to keep their HIV status private, which mostly involves the concealment of their medication. The number one goal of Pill Assist is to focus on the method of concealment in a way that integrates seamlessly into the daily lives of the average Ghanaian living with HIV. A lot of Ghanaians love to accessorize their possessions whether it is a phone case, a wallet, or a bracelet. Therefore, by creating a pill-taking device that can also be used as an everyday lifestyle accessory, the prototype can perform a multi-purpose use for the individual using it. The primary use of the device will be for pill-taking, while it can also be used as a keychain.

Overall, I learned that a design thinking approach is useful when dealing with stigma-related diseases like HIV/AIDS.

9 Conclusion

This research investigates the design of existing medication devices to identify gaps in addressing the needs of people living with HIV/AIDS for their medication adherence. The research focuses on stigma as a barrier to medication adherence. Research through design and health design thinking were approaches used to explore this issue. A review of the literature defined the need for and scope of the research, as well as identifying what is currently known about barriers and interventions for medication adherence. People living with HIV/AIDS (PLWHA) were then identified as the primary users, and data from the literature were then analyzed to inform design considerations that were used to help develop a concept and proposed designs for a solution that would help assist people living with HIV/AIDS in their medication adherence.

9.1 Design Considerations

This study generated a set of design considerations that should be kept in mind when designing solutions that assist in improving low medication adherence rates due to the stigma for people living with HIV/AIDS (PLWHA). The literature on design solutions that consider stigma as a barrier to adherence is limited. However, the literature expressed the need for more discretion in medication-taking devices as a way of keeping one's HIV status private.
Design considerations can be grouped into two categories: functional guidelines and experiential guidelines.

Four functional guidelines were identified:

- Allowing participants to easily and discretely carry the medication that they need
- Including reminders that are discrete yet effectively and reliably remind the user to take their medication.
- General functional guidelines such as making the device easy to use, sanitary, ergonomic, unisex, and low cost.
- Allowing refills of the device to be infrequent and simple.

Two experiential considerations were identified, which define some of the user needs relating to their behaviors and opinions. These include:

- Allowing for personalization of the device.
- Reducing or removing the stigma around taking medication

9.2 Hardware

When it came to selecting the hardware for this device, I prioritized my existing skillset with electronics. Most of the selected electronic components are better suited for prototyping purposes. New hardware components must be selected to create a device that can be used commercially and is more portable. This means that the prototype in its current state has been useful for providing insight for further development. For example, the 16x2 LCD screen that I connect to a microcontroller and buttons must be connected to a separate battery component. This makes it difficult when trying to integrate the solution into a wearable form factor.

Alternatively, I could investigate soldering the different components into proto boards, making things easier.

The use of more compact sensors and electronics such as an Adafruit Joy FeatherWing, an Assembled Adafruit FeatherWing OLED, and a Feather 32u4 Adalogger can therefore be considered. The Adafruit Joy FeatherWing has an in-built OLED screen and a microcontroller. The Adafruit Joy FeatherWing, has in-built buttons connected and the Feather 32u4 Adalogger has an in-built battery and storage. This will help me design a more compact prototype as well as eliminate the need for some additional wires with the circuitry. Being able to design a more compact prototype will allow the device to be easily portable and can allow for different types of form factors to be implemented that can help with the discreteness of the device.

9.3 Contributions

Three major contributions arose from this research. The first is a set of design considerations that can help guide the development of more solutions in this problem space. The second is the designs and prototypes that were made. The third is an expanded definition of wearable technology.

This study has led to a set of design considerations that are specific to the needs of stigma-related diseases such as HIV/AIDS. These design considerations were adapted from the "Wearables Design Requirements" which explored the role of human factors in wearables[81]. The adapted design considerations intend to expand on, and support current interventions seen in the contextual review and highlight issues that products in the market fail to address. The design considerations broadly cover functional and experiential guidelines that should be met to improve adherence. They are intended to guide the creation of new products that aim to improve low medication adherence rates due to the stigma for people living with HIV/AIDS (PLWHA). In addition, they are also intended to be used in validating whether existing products on the market are suitable for and meet the needs of this specific population.

[81] Francés-Morcillo et al., "Wearable Design Requirements Identification and Evaluation."

Through this research, a literature review was used to understand the issue of medication adherence in people living with HIV/AIDS(PLWHA). This perspective led to focusing on a specific market segment, exploring the unique needs, behaviors, and perceptions of people living with HIV/AIDS(PLWHA) in Ghana; whereas most of the literature around medication adherence and products aimed at improving it are tailored either to a general medication-taking population, or an older population.

The intended design of the Pill Assist prototype lends itself to the discussion around the design of pillboxes. The prototype designs are meant to expand on the design of current interventions that exist in the market and highlight certain areas these interventions often fail to address. Not all the current solutions on the market consider how the design of the product may improve adherence often prioritizing functionality only. However, I think both design and function are important. The new innovative designs try to integrate pill containers into everyday items people use while keeping medication-taking a private issue. These explorations intend to guide the future designs of pillboxes that cater to all types of medication needs, not just HIV/AIDS.

9.3.1 Wearables Definition

One of the outcomes of the research process was an expanded definition of wearable technology. Wearable technologies are defined as electronic devices that are physically worn by individuals to track, analyze and transmit personal data[82]. One of the key factors in the design process of wearable technology is finding a location on the body where the device can be worn[83]. While most definitions have focused on the physical definition of wearability, i.e., the position of a device to be worn on the body, this is not the only thing to consider in determining if a device is wearable or not. Dunne & Smyth define wearability as the degree of comfort (physical, mental, emotional, and social) afforded

[82] "What Is Wearable Technology? Examples of Wearables. | Built In," accessed May 1, 2022, https://builtin.com/wearables.

[83] Clint Zeagler, "Where to Wear It: Functional, Technical, and Social Considerations in on-Body Location for Wearable Technology 20 Years of Designing for Wearability," in *Proceedings of the 2017 ACM International Symposium on Wearable Computers*, ISWC '17 (New York, NY, USA: Association for Computing Machinery, 2017), 150–57, https://doi.org/10.1145/3123021.3123042.

by a body-mounted device, rather than the possibility of it being mounted on the body[84]. Wearables that seamlessly integrate with our 'body schema' tend to disappear from our consciousness, exist within our reach in our 'peripersonal space,' and therefore are easier to adopt[85]. The body schema refers to the size, shape, and physics of the human body. The peripersonal space is the spatial area that surrounds the body schema. In other words, a device becomes wearable when it is integrated into the body schema and becomes a part of the peripersonal space while a non-wearable device constantly demands a user's attention.

A wallet is an object that most people carry around them in their pockets daily. Using this definition from Dunne & Smyth, the final Pill Assist wallet prototype can be considered an example of a wearable accessory.

10 Future Work

10.1 Co-design

The next step for this thesis project is to invite the HIV community to participate in co-design and conduct user testing of the Pill Assist prototype. Using co-design, people can have their say in the design, form, and structure of the devices. This method is meant to contribute to the depth of this project since the device ideas created will be influenced directly by the HIV community and not just external influences i.e., people who are not living with HIV/AIDS. I intend to run a co-design workshop to invite members of the HIV community to participate. The goal of the workshop will be to generate ideas for potential devices. This will assure that the device design will be suited for the intended audience. I believe such workshops will also offer the opportunity to teach some basics of circuit design on a beginner level to those interested. I believe that adding this form of research methodology will help enrich the project and ensure that I am making decisions informed by the people living with HIV/AIDS themselves.

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[84] Lucy E. Dunne and Barry Smyth, "Psychophysical Elements of Wearability," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '07 (New York, NY, USA: Association for Computing Machinery, 2007), 299–302, https://doi.org/10.1145/1240624.1240674.

[85] Ibid.

10.2 Caregiver/Pharmacy Partnership

Something that I would like to explore as part of this research is potentially partnering with caregivers and hospitals for administering this device. This device could be given to the patient as part of their visit to the hospital or pharmacy once they are diagnosed and given their medication regiment to follow. This will help maintain the privacy of these devices to only people who are aware of their status. If these products were commercialized, the device will be at risk of exposure to non-people living with HIV/AIDS.

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12 Appendices

Appendix A - Strengths and Limitations of pill container vs wearable sensors

Table 2. Summary of main applications, strengths, and limitations of the current technologies used in medication adherence.

		Main Application Differences	Strengths	Limitations
Sensor Systems	**Smart Pill Container**	Detects cap opening and bottle pick up	Possibility to allow mobility Non-invasive	System's life is constrained by the battery Detect medication taking activity with low accuracy
	Wearable Sensors	Detects motions related to cap twisting, hand-to-mouth, pouring pill into the hand, and pill swallowing	Possibility to detect medication intake activity with high accuracy Relatively easy to use Allow mobility	User's comfort and social acceptance due to their possible invasiveness Require frequent battery charging or replacement
	Ingestible Sensors	Detect pill ingestion	Possibility to detect concurrent pills ingestion Allow mobility	User's comfort and social acceptance System's lifetime is constrained by the battery Security issues due to their limited resources
Proximity-Based Systems		Detects medication presence or absence within the proximity of reader's antenna	Non-invasive	Need to be coupled with other monitoring or sensing techniques for verification
Vision-Based Systems		Detects medication presence or absence within the scope of the camera	Non-invasive	Need to be coupled with tech or sensing techniques for verification
Fusion-Based Systems		Try to verify the operation of monitoring the medication taking activity	Higher accuracy as compared to standalone technology	Resource consuming Do not usually support mobility

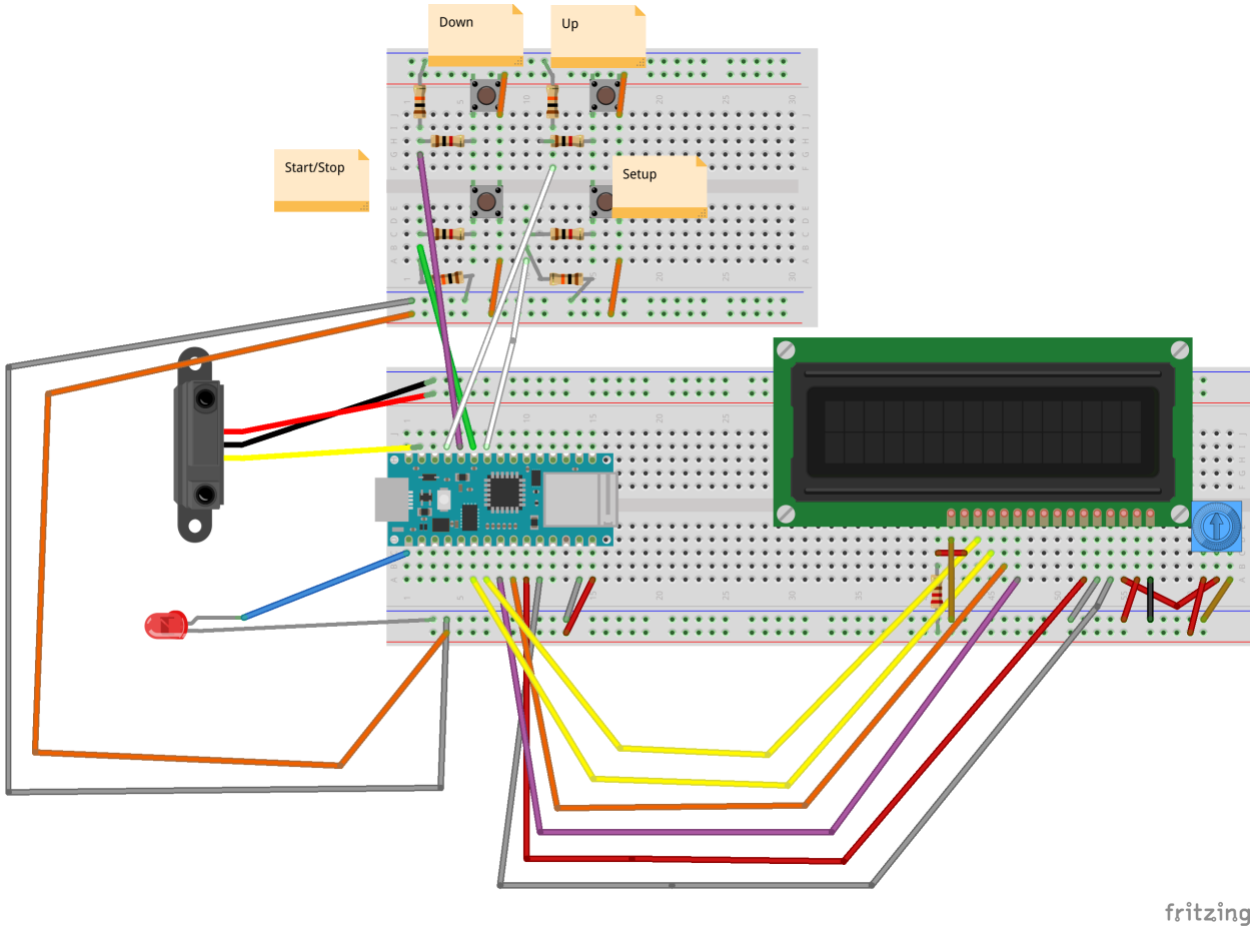
Sources: Data from Aldeer, Murtadha, Mehdi Javanmard, and Richard P. Martin. "A Review of Medication Adherence Monitoring Technologies." Applied System Innovation 1, no. 2 (2018). https://doi.org/10.3390/asi1020014.

Appendix B - Table showing Wearable design requirements, parameters, and definitions

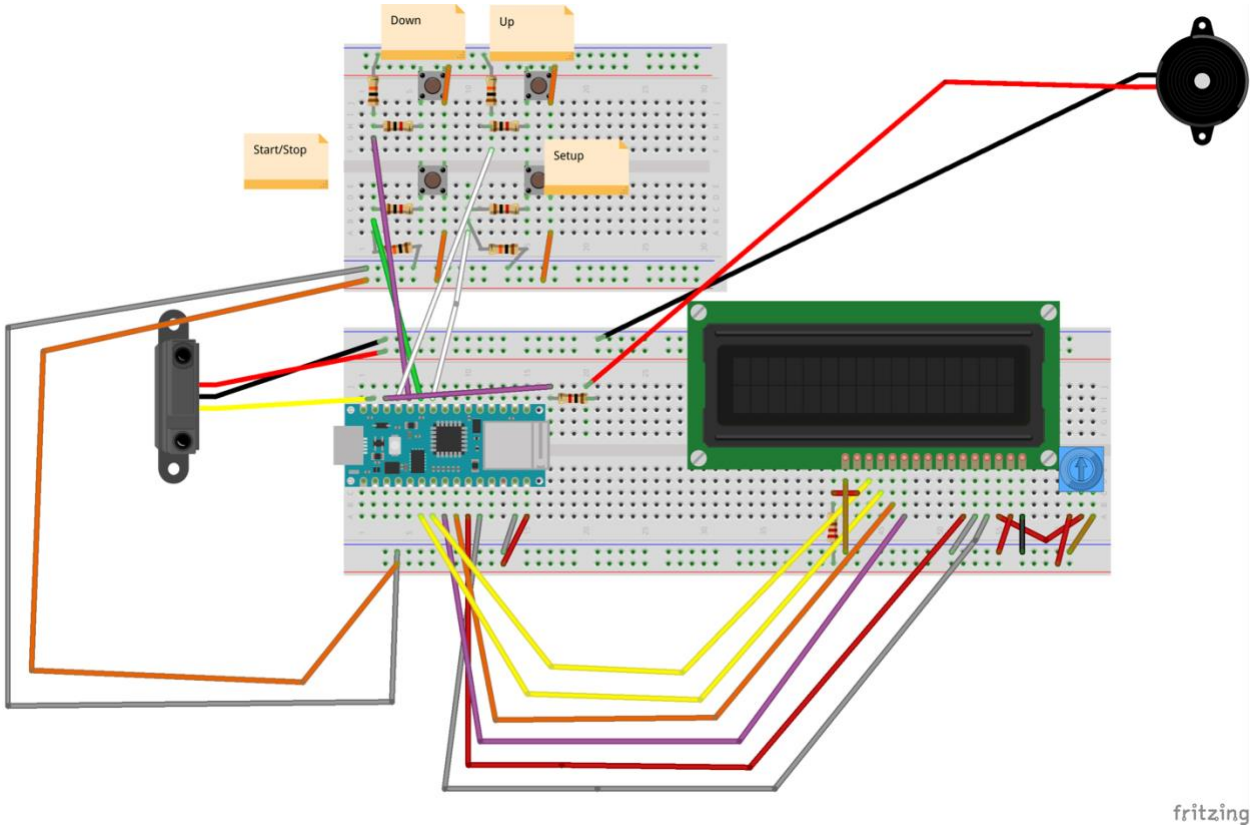
Requirement	Parameter	Parameter Definition
Comfort	Shape	The adjustment to the body region is the proper one
		The device is properly attached to the user and there is no danger of losing it.
		The device fits the shape of the body region.
		It is easy to put and take off the glove.
	Breathability	The device is breathable and it avoids the accumulation of sweat.
		The device has some slack to circulate air without compromising fit hand.
	Hygiene	The device can be washed.
	Temperature	The temperature does not increase above the recommended value.
		The protection of heat in the glove does not cause pain.
	Sizing	The device adapts to all the target users' size.
	Obtrusiveness	The device does not cause fatigue or decrease the comfort.
		The device enables the natural body movements.
	Weight	The device is light.
	Movement	The device is sufficiently flexible to allow the natural movement of the body region.
Safety	Harm	The device is safe it does not cause pain to the worker.
		All the device components are properly attached.
		Heat dissipating devices are separated from the user skin.
	Anxiety	The device is properly used by workers.
Durability	Resistance	The device is resistive for all the life cycle previously identified.
		The device is properly protected from external elements (e.g., hand tools).
Usability	Intuitiveness	The user understands the interaction with the device in an intuitive way.
	Simplicity	The device is easy to use and the feedback is presented in a simple manner.
Reliability	Precision	The device is accurate.
	Effectiveness	The device meets the function and the final result is achieved.
Aesthetics	Fashion	The device is coherent to the aesthetical and fashion that have been defined.
	Form language	The device form language is coherent to the defined one.
	Customization	The device is customizable.
Engagement	Long-term use	The device has a long-term use.
	Engagement	The device is appealing for the user and he/she feels the need of having it.
Privacy	Privacy	The exchange of information is discreet and keeps user confidentiality.
	Subtlety	The interaction with the device is respectful with other people nearby.
Functionality	The glove works properly (components work individually and all in all with the glove).	
Satisfaction	The user is satisfied with the glove.	

Sources: Data from Francés-Morcillo, Leire, Paz Morer-Camo, María Isabel Rodríguez-Ferradas, and Aitor Cazón-Martín. "Wearable Design Requirements Identification and Evaluation." Sensors 20, no. 9 (May 2, 2020): 2599. https://doi.org/10.3390/s20092599.

Appendix C – Early Electronic Prototypes



The second physical prototype iteration was tested using visual feedback, auditory and tactile feedback. Visual feedback was the first thing I experimented with. When the alarm goes off the LED flashes to alert the user that it is time to take their medication dosage. The LED goes off once the user has picked the medication dosage. This makes it easy for the user to see this wherever they are. However, this kind of notification is easily noticeable to others and will draw attention to the device. This was tested out to confirm the earlier hypotheses



The next experiment used a DC Buzzer to produce auditory feedback. Whenever the alarm goes off to alert the user of their medication intake, the buzzer produces a noise acting as a reminder for their medication. Just like the LED is easy to see, the sound is easy to hear and can easily be noticed by others.