

# Enhancing Medicine Adherence through Multifaceted Personalized Medicine Management

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**Abstract**—Medicine adherence is a growing problem that affects not only patients but also the healthcare industry. In this short paper, we represent a brief overview of the severity of medicine non-adherence, especially to elderly patients of chronic conditions, and the reasons behind the phenomenon. A generic survey of the existing methods of interventions to aid in medicine adherence is then discussed, followed by the identification of the lacking areas that such interventions could not address. The need for a multidisciplinary approach that incorporates features of personalized medicine management towards addressing the problem is then explored, investigating the possible solutions through the establishment of concordance and instilling behavioral changes in patients through education and motivational strategies. The paper will then focus on an ongoing research and development work in the form of a medicine dispenser which attempts to bring under a single platform the multifaceted approach to address medicine adherence and the benefits that ensue.

**Keywords**—adherence; chronic; concordance; elderly; healthcare; interventions; personalized medicine management

## I. INTRODUCTION

Medicine adherence (and the lack thereof) has been one of the major challenges faced by the healthcare industry in recent times and is a growing problem for the elderly of all ages as they are most likely to mismanage their medicines [1], [2]. The detrimental consequences of medicine non-adherence impact not only the patients as they suffer from ineffective treatment outcomes leading to higher long-term healthcare costs, as well as the pharmaceutical manufacturers in terms of loss of revenues due to patients failure to refill prescriptions. This potential loss from non-refilled prescriptions is exacerbated in patients with chronic diseases and is reported to be up to \$8 billion per year [3]. On the other hand, the healthcare system is affected in having to bear heavier healthcare costs due to increased hospitalization rates and clinical consultations. A further \$50 billion was reported to be incurred in lost productivity due to medicine non-adherence [4]. The extent of adversity of this phenomenon is vast and has been described by the National Council on Patient Information and Education (NCPIE) as “America’s other drug problem.” Special populations at risk in medicine non-adherence include those suffering from chronic diseases, especially among people aged

65 and over as they take more medications as they age. This group of patients need to be treated with more attention compared to the others to ensure they understand the need for medications and the role it play in the management of their condition [5].

According to the World Health Organization (WHO), chronic diseases accounted for 60% of all deaths in the world, forming the leading cause of mortality [6]. Development of assistive technologies to support aging in place and improve the quality of life for chronic disease patients will see prominence to cater to the needs of the worldwide aging population as they suffer from long-term medical conditions that are generally progressive. Indeed, the severity of the situation warrants research and discussion, which this paper will investigate with regards to the reasons leading to medicine non-adherence and limitations of existing solutions. For these reasons, we are working on an ongoing project to design and develop, a medicine management system which encourages medication adherence using educational and behavioral approaches.

## II. ANTECEDENTS AND CONSEQUENCES

### A. Reasons for medicine non-adherence

It has been documented that up to 50% of Americans are not taking medications as prescribed and the total costs to the healthcare system in monetary costs is an estimated \$300 billion [7]. The same percentage of medicine non-adherence has also been observed in patients with chronic medications and averages 50% [8]. One of the main reasons for medicine non-adherence that elderly patients attribute to is forgetfulness. Other reasons include difficulty in adhering to complex medicine regimes [9], particularly in cases where patients suffer from multiple morbidities which require multiple drug therapy [10]. This phenomenon has undoubtedly become one of the main factors leading to exacerbation of the conditions of chronic diseases [11], [12]. Other factors that contribute to failure in medication adherence include lack of awareness of the benefits of their medications, poor relationship and communication with health care providers [13], and intentional non-adherence mainly due to patients not seeing any improvement in their conditions after taking medicines. More

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importantly, a survey of 10,000 patients conducted by Harris Interactive and the Boston Consulting Group (BCG) [14] revealed that reasons leading to medicine non-adherence are multi-dimensional and can be patient-initiated, as shown in Fig. 1.

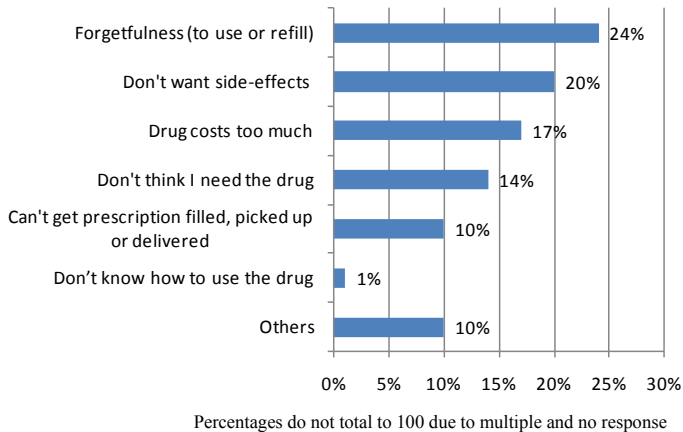


Figure 1. Graphical representation showing reasons for medicine non-adherence.

### B. Solutions and problems to support medicine adherence

The rapid development of technology-assisted medicine management strategies has proved to aid medicine adherence in patients [4]. Medicine management devices, like the ubiquitous pill boxes, serve the purpose of easy dosing and to a limited extent, simplifying medicine regimens. However, they do not aid in reminding the patients in taking their medicines, a necessary feature due to the often deteriorating cognitive abilities of the elderly. Intelligent lids that emit visual reminders go a step further to address this issue by providing visual, and sometimes, audio cues to remind patients of when it is time for medication. Microchips that can be embedded onto the packaging (for example, blister packs) of medicines allow the monitoring of the dates and times when the package is opened and thus records patients' medication taking patterns. More comprehensive devices include electronic medicine dispensers that dispense medicine, remind patients, and send an alert to a third-party (usually the caregiver) if a dosage is missed or skipped.

While these and various other methods and devices are helpful in enhancing medicine adherence, a major challenge lies in the exhibition of long-term adherence as these behavioral actions is shown to deteriorate over time even as patients started off as being very diligent [15]. This situation is exemplified in patients with chronic conditions as their adherence rates have been found to decline over time [16], hence leading to the progression of their conditions. While devices like the pillbox and intelligent lids perform the functions of reminding, thus potentially solving the problem of patient forgetfulness in taking medications, as well as simplifying complex medicine regimens, they do not address intentional non-adherence behavior that are initiated by the patients. Issues like lack of knowledge of their drug therapies, including unawareness of the benefits and timeframe needed to produce the intended effects [17] and concerns of side effects all contribute to the prevalence of medicine non-adherence.

However, such barriers to adherence are often not addressed by most existing medicine management methods and devices.

## III. A MULTIDISCIPLINARY APPROACH TO MEDICINE ADHERENCE

Traditionally, intervention strategies to enhance medicine adherence in the form of medicine management methods and devices have been focused in the areas of simplifying medicine regimens and its delivery. In more recent times, there is a growing recognition that a multifaceted approach to improving medication adherence behavior is mandatory for the behavior to be sustained over the long-term. Undoubtedly, intervention strategies that involve an extent of personal contact or counseling with a healthcare professional are generally more effective than strategies that rely solely on non-personal interventions such as intelligent packaging or automatic reminders. The significance of this recognition is highlighted by the WHO in its 2003 report [18] where it called for a multidisciplinary approach towards improving medicine adherence.

### A. Establishing concordance

A foremost priority in the multidisciplinary approach is improving the interactions between healthcare professionals and patients to create concordance, which is intended to convey an active partnership between the patient and the healthcare professional [19]. This involves enhancing patient education and communication in the dissemination of information on the conditions and medicines involved. Accordingly, with ensuing improved communications, the level of trust between the healthcare professional and the patient will inevitably increase, thereby mitigating levels of confusion for patients [20], [21]. By creating opportunities for open discussion during clinical consultations, the patients would be able to engage in shared decision making with regards to their conditions and medicine prescriptions [22]. Through interactive two-way discussions, healthcare professionals will be able to simplify medication regimens by identifying and discontinuing medications that are unnecessary, as well as address other medication-related issues that inhibits adherence.

### B. Instilling behavioral changes

Another significant barrier to medicine adherence stems from the patients' attitudes and beliefs towards medicine taking. Some of the reasons, amongst others, for intentional medicine non-adherence exhibited by patients include misconceptions about the nature and severity of their illness, denial of illness and the need for proper medications, disbeliefs about the effectiveness of the prescribed drug therapies, concerns about the social stigma associated with taking medicines, lack of confidence in the ability to follow the medication regimen, and absence of positive motivations and incentives to make necessary changes in behavior [23].

Addressing the challenges posed by intentional non-adherence requires behavioral reinforcement and patient support strategies throughout the continuum of care [14]. Such methods could consist of behavioral approaches that involve, for example, establishing a buddy system between patients or

providing supportive home visits. The deployment of educational approaches could also be included to provide clear and concise dosing instructions to patients to increase knowledge and reduce confusion. Such a combination of behavioral and educational approaches under a single platform is more likely to produce optimal results in reducing intentional medicine non-adherence [24].

#### IV. A HUMAN-CENTERED DESIGN OF MEDICINE DISPENSER FOR MULTIFACETED PERSONALIZED MEDICINE MANAGEMENT

Electronic medicine dispensers that comprise the functions of storing, reminding, dispensing the correct amount of medicines and logging the medicine-taking patterns of patients are not uncommon and have been reported to show some improvements in patient medicine adherence. However, such electronic devices often fail to assess the pervasive reasons why patients are non-adherent with their medicines [25]. The multitude of factors leading to medicine non-adherence requires a combination of multifaceted interventions involving both educational and behavioral approaches to overcome. Using the recommendations that the NCPiE has outlined and a range of communications-based strategies for improving medication adherence [26], a medicine management system consisting of a human-centered design of a medicine dispenser and web portal designed for home-based use and as part of an ongoing research and development study is described as follows.

The medicine management system includes a medicine dispenser (Fig. 2) and a web portal. The medicine dispenser stores medicine pills, reminds patient when it is time for medication and dispenses the right dosage to the patient. The web portal receives and stores medication data from the medicine dispenser. The automatic reminders and correct dispensing of dosage by the medicine dispenser serve to increase the patient's confidence in his or her ability to follow the medication regimen. To educate the patient to better understand their condition and drug therapy, both the medicine dispenser and web portal would incorporate the function of providing medicine information that are personalized to the patient's needs.



Figure 2. Paper prototype of a human-centered design of medicine dispenser.

Displayed through an integrated interface on the medicine dispenser, useful information including the medicine's purpose, benefits, cautionary instructions, possible side effects and their management in a customizable language would be provided to the patient. More detailed medicine information is also displayed via the web portal. This will aid in alleviating the patient's lack of awareness of the medications, hence enhancing the appreciation about the value of the medicines when properly administered. With better knowledge about his or her condition and the intended effects of the medications, reasons such as denial of their conditions and the benefits of their drug therapy that lead to intentional non-adherence can potentially be subverted.

The medicine dispenser logs the patient's medicine intake history and sends the data to a web portal. This enables both healthcare professional and patient to access daily, weekly or monthly reports of the patient's medicine intake history, providing them with insights and better understanding of the patient's medicine taking patterns. Motivational strategies in the form of words of encouragement to reinforce desirable behavior could be incorporated in the reports, for example, *"You have achieved 100% adherence for your medications for the month of March 2011. Well done and to good health!"* Using these reports as a mutual aid to both the healthcare professional and patient during clinical consultations, opportunities to elicit patient's feelings about his or her ability to follow the regimen and customization of the regimen in accordance with the patient's needs can be optimized. The patient is also more likely to engage in meaningful open discussion with the healthcare professional, knowing that the healthcare professional is reading the same adherence report, thereby reinforcing his or her own behavior and attitude towards working in alliance with the healthcare professional. With improved communications, the healthcare professional would also be able to recommend supports to promote adherence, for example, through help from the patient's family and friends, and community services, as well as reinforce desirable behavior and results when appropriate. Such outcomes align with the aim of instilling concordance in the partnership between healthcare professionals and patients.

Integrating functionalities of personalized medicine management could also include providing customized voice instructions and encouragement that can be programmed into the medicine dispenser. For example, a daughter of an elderly patient could record verbal instructions in her own voice (*"Mom, it's now time to take your medicine. Call me if you need any help. Have a nice day and I love you."*), and the medicine dispenser would sound off this instruction as an audio cue when the time for medication is due. Customized motivational encouragement could also be sounded off at the end of the day or dosing schedule to reinforce desirable behavior (*"Mom, you've taken all your medicines on time today, I'm so proud of you! Let's look forward to the summer holiday at the beach!"*), or to motivate better medicine adherence the next day (*"Mom, you've missed taking the afternoon dose today. Don't be disheartened, let's try and do better tomorrow. I love you."*).

## V. CONCLUSION

The ultimate goal of introducing interventions to improve medicine adherence in patients is to improve health related outcomes. This would prove to be of special significance to elderly patients of chronic diseases due to their multiple drug therapy on a continuing basis. However, most existing interventions in the forms of pillboxes and electronic devices are single-focused, failing to recognize the importance of employing a combination of strategies to address the problem. Various studies and government initiatives have recognized the growing need to adopt a multidisciplinary approach towards enhancing medicine adherence in patients. In this paper, we discussed the importance of open communications between healthcare professionals and patients as a feature to establish concordance between the two parties. The need to change patient attitudes through education and behavior reinforcement was also discussed so as to alleviate intentional non-adherence as patients learn to acknowledge their medical conditions and the importance of the drug therapies.

A medicine management system consisting of a human-centered design of a medicine dispenser and web portal as part of an ongoing work was then introduced to represent a multifaceted strategy of intervention to enhance medicine adherence. By integrating practical, educational, motivational and personalized strategies in its functions, the medicine dispenser aims to address the core reasons behind non-adherence, thereby mitigating the problems that may arise out of poor communications with healthcare professionals, lack of awareness of medical conditions and their related medications, and lack of positive motivations and incentives to make necessary changes in behavior. This design underlines the importance of the recognition that interventions should be multifaceted and combined under a single platform to produce optimal results in the achievement of medicine adherence in patients.

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