

Improving Medication Adherence Behaviors Through Personalized, Technology-Powered Interventions

Jacob T. Biehl^a, Ravi Patel^b and Adam J. Lee^a

^a*School of Computing and Information, University of Pittsburgh, 135 N Bellefield Ave, Pittsburgh, PA, USA*

^b*School of Pharmacy, University of Pittsburgh, 3501 Terrace St, Pittsburgh, PA, USA*

Abstract

The World Health Organization refers to non-adherence as a worldwide problem of striking magnitude. Non-adherence leads to worsened medical conditions, increase comorbidity of disease, or death. Clinical studies have shown the most effective strategies for adherence are those that are individualized to the context that each patient and situation require. Yet, existing aids are relatively ridged and poorly support adaptation to individual behaviors and lifestyles. We believe our work in this space is relevant to the HEALTHI workshop. Broadly, we are eager to engage in scholarly conversations and collaborations which seek to improve the research community's ability to move beyond one-size-fits-all approaches to the design and construction of technologies to improve human health.

1. A Global Problem

Prescription pharmaceuticals are an essential component of modern healthcare. Yet, globally, it is estimated that nearly 50% of patients do not properly adhere to their medications [1]. Despite the scale of the problem, the number of effective technology aids and interventions to improve adherence are quite small compared to the size of the healthcare technology market. The lack of successful technology is not for lack of research, as our community has deep contributions to study and technology development [2, 3, 4, 5, 6, 7]. All prior technology investigations agree with the clinical research, which show adherence is highly dependent on individual situations and sentiments that define and moti-

vate behaviors [8]. In particular, past work has shown utility is greatest in interventions that are highly customized to address the specific barriers preventing adherence. It argues there needs to be a broad shift towards highly individualized, consumer-level healthcare tools.

These lessons of past technical and clinical work must guide the design and development of future health technologies; specifically the need to employ methods that seek solutions that easily integrate and support highly specialized, personal behaviors. Towards this goal, we believe the maturity and acceptance of in-home sensing, machine learning, and lightweight input/output devices (such as smart speakers) present contemporary opportunities to develop novel approaches to personalized adherence aids.

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✉ biehl@pitt.edu (J.T. Biehl); rmp40@pitt.edu (R. Patel); adamlee@pitt.edu (A.J. Lee)

ORCID 0000-0002-3878-5208 (J.T. Biehl)



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2. Towards Hyper-Personalized Tools

There are already many examples of machine learning and sensing technologies that support personalized interventions. For example, wearables can provide notifications and reminders, smartphone apps can help users catalog and organize medication dosing instructions, and smart pill bottles can accurately monitor for when medications were taken. These existing solutions, though, do not offer the promise of true personalized behaviors change. Sending a notification, or capturing time of doses, are not sufficient for sustained behavior change. These technologies must integrate across dimensions of technology innovation; which include cost, scalability, inclusion, accessibility, and efficacy while also spanning stakeholders; which include individuals, family and friends, community, health systems, and government policy.

Over the past year, we have been investigating opportunities for technology and community integration using sensing, machine learning, and lightweight I/O. We briefly describe these efforts as evidence of our ability to contribute to a rich discussion of advancing health-based interfaces and technologies at the workshop.

2.1. Provider Involvement

Truly hyper-personalized technologies are those that support and strengthen the connection between a patient and his/her/their providers. We have conducted over twenty in-depth, multi-hour interviews with hyper-tensive patients to better understand adherence practices and how those practices influence the interaction with the healthcare providers. In our interviews we investi-

gated patients' comprehension of medications' purpose and dosing, as well as how their care providers participate and influence this comprehension. As expected, interviewees provided a strong understanding of why they were taking their prescribed medications and what the resulting health benefits should be; topics that were clearly discussed as part of the patient-provider interaction. Less clear was when medications should be taken, how they should be monitoring interactions and side effects, and how to improve their adherence to the medications; topics typically not germane to patient-provider conversations or to the role of providers.

Through these interviews, we also presented interviewees with several hypothetical technologies, including those that used sensing and machine learning to share information about patients with providers. In particular, we described a technology that would analyze behaviors pertaining to when medications were taken, where they were stored, and a persons activities within their home. We explained this data would be collected, summarized, and presented to providers to seed discussions on more efficient strategies for adherence, including changing dosing, medication selection, or behavior modifications. Reaction to these technologies was mixed, but many respondents indicated a desire to use the technology, as they found it would help providers understand that they are trying and to accelerate recommendations and changes that were specific to their individual struggles. In essence, they saw the technology as useful in cutting through the boilerplate recommendations and feedback to engage with providers on personal terms.

2.2. Proactive, Not Reactive Aids

A significant proportion of the personalized health technologies are designed to provide

reactive opportunities for users. For instance, health tracking apps can keep track of steps taken or calories burned, and provide those summaries to user for them, in turn, to translate the knowledge into action. Similarly, medication tracking applications and smart pill bottles can inform users when they miss a dose; again, providing knowledge that must be turned into action. Future technologies, with the capabilities of pervasive sensing and advances in behavior modeling, should leverage the constant stream of information about the user to be proactive, rather than reactive in design.

In our interviews, described above, we also explored user reaction to technologies that were proactive in design. Some were very simple; for instance, using proximal location and knowledge of a pending dose to nudge a user to take their medication when they happen to be near the bottles, rather than at the scheduled time when it may be physically inconvenient. Other hypothetical technologies were more complex, suggesting locations for medication storage and times of dosing based on physical, historical behaviors in the home. For instance, suggesting medication be kept in the kitchen and taken in the morning because the user consistently makes coffee in the morning. In this case, the technology can proactively help users form medication habits consistent with their activities of daily living.

Feedback on these approaches were positive, but with concerns about overreach. In particular, integrity of the data and how and who it would be shared with was a consistent concern. Interviewees expressed this concern in way that were less about outsiders watching their activities, but about whether this data would be used to negatively impact their care. For instance, sharing information with insurance providers or employers. The results of these early insights point to the value of proactive, AI-driven tools; but must

be limited in reach to achieve user trust.

2.3. Aids Which Promote Independence

Increased technology interventions, especially those that use pervasive sensing or those that communicate and report to care providers travel a thin line between enabling and dictating a patient's independence. Our investigations have proved that personal health maintenance is an extraordinarily private activity for most people. When asked in our interviews if other members of their home help them to remember to take their medications, we often received responses to indicate such dependence was not preferred, as it was perceived as an unnecessary burden on the other household member and a admission of not being able to handle the responsibility on one's own. This was true for living situations from roommates to intimate partners in decades-long marriages.

As we look forward to design technologies that provide significant levels of personalizing through both technology pervasiveness and increase integration with daily activities and health provider interactions, we must be keen to do so from a perspective of preserving individual independence.

2.4. Leveraging Existing, Pervasive Technology

Important to the vision of proactive, independence promoting aids, is the ability to leverage new forms of pervasive technologies for patient interaction. We believe the application of these technologies remains understudied. One such example is the success of short message service reminders in delivering health-based reminders. While more basic than current technology, this method of notification nearly always finds improved patient medical compliance [9]. While this

method is successful in engage patients, its traditionally static deployment can be made more dynamic to proactively time notifications relevant to behaviors related to medical adherence.

In addition, we believe these existing approaches can be used in combination with other emerging technologies, such as voice activated technology assistants and smart speakers. Industry reports find that nearly 20% of households own at least one smart speaker¹. The use of these technology to monitor and improve health behavior is limited compared to the vast literature exploring other internet of things devices, particularly within the design space of proactive, dynamic engagements with patients; either alone, or with their providers. In particular, we believe this approach can create engagements with aids that can improve and support patient health behaviors over the long term.

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¹<https://techcrunch.com/2020/03/24/infinite-dial-2020/>

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