

# Can Technology Solve the Problem of Medication Nonadherence?

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## The Burden of Nonadherence

In the United States, over 3.8 billion prescriptions are written annually.<sup>1</sup> Medication adherence, or taking prescription medication as directed, is an essential part of patient treatment. Nonadherence is a major public health problem with numerous implications, both for an individual's health and population health. Studies have shown over 50% of adults do not achieve adherence to their medications contributing to as many as 125,000 deaths and between 33% to 69% of hospital admissions annually and placing a significant financial burden on the health care system.<sup>2–4</sup> The World Health Organization states that increasing the effectiveness of adherence interventions may have a far greater effect on the population's health than any improvement in specific medical treatment.<sup>5</sup>

## Barriers to Medication Adherence

More medications are administered by patients and families in home-based settings than by clinicians in hospitals and clinics combined, making medication adherence largely the responsibility of patients.<sup>2,3,6</sup> Unfortunately, home-based settings are associated with medication nonadherence and little if any guidance is given to patients on how to be adherent to their prescriptions.<sup>7–10</sup> Many factors can affect medication adherence, whether on an individual level or a system-wide level; examples include patient comprehension, prescription cost or supply, or social pressures.<sup>11</sup> These factors interrupt the process of medication adherence, which can be further broken down into 3 components: initiation, implementation, and discontinuation.<sup>12</sup> Nonadherence occurs when any of these components are affected, such as the failure to start treatment, issues with maintaining the prescribed regimen, or discontinuing the treatment early.<sup>12</sup> Using this taxonomy, forgetting to take medication, which affects

implementation, is one of the most common unintentional barriers to medication adherence and is a particularly ripe area for digital health interventions to support home medication management.<sup>11</sup>

## The Role of Digital Technologies

Although forgetfulness is one of the major barriers to medication adherence in patients' homes, it is one that may benefit most from interventions involving digital technologies. Traditional aids to medication adherence are quite prevalent in retail pharmacies and online in the form of pill cases with separate compartments for the different days of the week.<sup>13</sup> However, digital devices are becoming more common to address medication adherence. On the simplest level, these include the use of a smartphone, smartwatch, or home assistant to set alarms or notifications. For users of prescription bottles, products like the GlowCaps lid can help with adherence by recording when the bottle was opened and uses auditory or visual cues to alert the patient when it has not. Pill cases have been enhanced with timed notifications and sensors indicating when a pill case compartment has been opened. Some devices, like Hero and Med-Minder, are dispensers with timed notifications and associated applications. Recording that a medication was taken—or at least removed—opens up possibilities of monitoring adherence behavior and notifying family caregivers or emergency contacts. Applications are prevalent tools for managing a medication schedule, either standalone or as part of a cap, container, or dispenser. Popular examples include the MediSafe application<sup>14</sup> and the Medications application on the Apple Watch, which offer features such as notification reminders, symptom tracking, and medication history. A survey study by the first author with 1673 respondents found that the 19% of respondents using

smartwatches to remind them to take their medication reported the lowest rate of ever forgetting to take a medication. The smartwatch was the only digital reminder method that was significantly associated with self-reported adherence. Of note, the Apple Watch added a medication application, but only after the survey was conducted.

Many of these devices and applications rely on time-based reminders, where a visual or auditory alarm or text notification is triggered at a specified time of the day. These occur daily and are automatic, regardless of where patients are or what they are doing, including that they may have already taken medication or may not be positioned to hear or see the alert. Whether the alert comes through the device itself or goes directly to the patient's smartphone or smartwatch, and whether there are any additional features offered, depends on the type and complexity of the technology. In an interview study with older adults conducted by the first author, the majority (91%) of the 22 participants took their medication during a time range tied to a routine, whereas only 9% reported taking medication at an exact time every day. Daily schedules often have inherent flexibility, thus time-based reminders maybe an artificial construct that is more annoying than helpful.<sup>15</sup>

### Limitations of Digital Technologies for Medication Adherence

Despite the many digital devices available, adherence continues to be an unresolved public health problem. Although alerts can be effective initially, their long-term sustainability and effectiveness are uncertain. Furthermore, most devices and applications lack health care provider or patient involvement during development,<sup>16–18</sup> which would help ensure patient needs are being met and may lead to high quality and reliable content and even evidence-based design.<sup>13</sup> Notification or alert fatigue, a term coined for the large volume of notifications an individual can receive on a smartphone or smartwatch, can result in people ignoring or turning off the alerts. Most notification-based systems are triggered regardless of whether the medication was taken or not, which likely negatively affects the effectiveness of the notification system

over the long term.<sup>16</sup> Finally, although applications that ask about missed doses and document information about side effects provide useful information to physicians, patients need to self-report that information. Although self-reporting maybe plausible for short-term medications, those looking to build long-lasting habits are unlikely to continue to record this information manually, which can potentially lead to unreliable reports. If an individual misses a dose of medication, they may also miss recording this in their application.

### Bolstering the Effectiveness of Digital Technologies

If new technologies are developed to improve medication adherence, a shift away from time-based reminders could be beneficial. Patients who are trying to develop a medication regimen are adding a new habit into a pre-existing daily routine. An activity-based reminder that is only activated when needed, as opposed to at the same time daily, maybe more acceptable to patients as these reminders are designed to remain invisible until triggered. An approach, the authors are developing uses a failsafe approach that mimics that of a seatbelt alarm, which is only activated when both the ignition is turned on and the seatbelt is not latched. In the case of medication adherence to a morning dose, the failsafe could be tied to a daily morning activity. Would patients respond to notifications triggered if they made their morning coffee but had forgotten to take their pills? This example could be personalized to the individual's routine, whether the failsafe is triggered by coffee making, opening a bureau drawer or closet, using a toothbrush, or taking a shower. The design of this intervention focuses on portability, to accommodate travel when environments and routines may change. Such technology may especially interest older adults, who are motivated by a desire to live independently for as long as possible.<sup>19</sup> Other novel approaches include those that use mathematical modeling to recognize patient medication-taking behavior,<sup>20</sup> recognize the hand motions associated with taking medication,<sup>13</sup> or deploy specialized pill bottles that register when they have not been opened at the right time.<sup>14</sup> Further exploration is needed of concepts using as-needed reminders rather

than daily ones, and evaluating not just the benefits and effectiveness at improving adherence, but also potential drawbacks, such as cost, ease of setting up, and ease of using.

Although new technology is a vast area to be explored, current technology need not be abandoned. Is there a way to leverage existing tools to better support medication adherence? What methods might bolster their effectiveness? For instance, research by the first author found several medication storage locations that were significantly associated with not forgetting to take medication for middle-aged and older adults. Patients who chose a nightstand, for instance, had better adherence than those who used their kitchen cabinets.<sup>19</sup> Could changing the location where medication is kept—and even optimizing selection for a patient's first prescription—improve adherence? Going 1 step further, could we design nightstands optimized for medication containers or design medication containers optimized for nightstands? The only location in many homes that is seemingly designed for medication is the medicine cabinet, but the first author's research found that it was not associated with adherence. Furthermore, the use of it presented concerns about medication safety because of exposure to temperature and humidity. Finally, new approaches, such as co-design to include patients as designers, not just recipients of designs, may lead to innovations that fit better into patient lives and are a pleasure to use.<sup>18</sup>

## CONCLUSION

Despite the limitations of currently existing medical devices and applications, there is a role for technology in improving medication adherence. The authors propose innovative approaches that may increase the effectiveness of adherence devices and therefore have a greater impact on improving adherence. The timing is right to introduce new interventions, as there is a rising trend in medication nonadherence across all age, sex, and racial groups in the United States, and smartphone and smartwatch use is highly prevalent.<sup>21</sup> With the right combination of tactics, digital technology could address a serious public health problem, resulting in reduced hospitalizations and deaths, billions of dollars saved, and more adults able to live independently for longer.

## POTENTIAL COMPETING INTERESTS

The authors declare no conflict of interests.

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## REFERENCES

1. Neiman AB, Ruppert T, Ho M, et al. CDC Grand Rounds: Improving Medication Adherence for Chronic Disease Management — Innovations and Opportunities. *MMWR Morb Mortal Wkly Rep*. 2017;66(45):1248-1251. <https://doi.org/10.15585/mmwr.mm6645a2>.
2. Bouwman L, Eeltink CM, Visser O, Janssen JJWM, Maaskant JM. Prevalence and associated factors of medication non-adherence in hematological-oncological patients in their home situation. *BMC Cancer*. 2017;17(1):739. <https://doi.org/10.1186/s12885-017-3735-1>.
3. Benjamin RM. Medication adherence: helping patients take their medicines as directed. *Public Health Rep*. 2012;127(1):2-3. <https://doi.org/10.1177/003335491212700102>.
4. Cramer JA, Roy A, Burrell A, et al. Medication compliance and persistence: terminology and definitions. *Value Health*. 2008;11(1):44-47. <https://doi.org/10.1111/j.1524-4733.2007.00213.x>.
5. Adherence to long-term therapies : evidence for action. World Health Organization. <https://apps.who.int/iris/handle/10665/42682>. Accessed November 6, 2023.
6. Cross AJ, Elliott RA, Petrie K, Kuruvilla L, George J. Interventions for improving medication-taking ability and adherence in older adults prescribed multiple medications. *Cochrane Database Syst Rev*. 2020;5(5):CD012419. <https://doi.org/10.1002/14651858.CD012419.pub2>.
7. Home R, Weinman J, Barber N, et al. *Concordance, Adherence and Compliance in Medicine Taking*. NCCSDO; 2005.
8. Wiecekiewicz SM, Kassamali Z, Danziger LH. Behind closed doors: medication storage and disposal in the home. *Ann Pharmacother*. 2013;47(4):482-489. <https://doi.org/10.1345/aph.1R706>.
9. Gandhi TK, Weingart SN, Borus J, et al. Adverse drug events in ambulatory care. *N Engl J Med*. 2003;348(16):1556-1564. <https://doi.org/10.1056/NEJMsa020703>.
10. Rantz MJ, Zwiggart-Stauffacher M, Popejoy L, et al. Nursing home care quality: a multidimensional theoretical model integrating the views of consumers and providers. *J Nurs Care Qual*. 1999;14(1):16-37. quiz 85.
11. Chan AHY, Cooper V, Lycett H, Home R. Practical barriers to medication adherence: what do current self- or observer-reported instruments assess? *Front Pharmacol*. 2020;11:572. <https://doi.org/10.3389/fphar.2020.00572>.
12. Vrijens B, De Geest S, Hughes DA, et al. A new taxonomy for describing and defining adherence to medications. *Br J Clin Pharmacol*. 2012;73(5):691-705. <https://doi.org/10.1111/j.1365-2125.2012.04167.x>.
13. Wang D, Gualtieri L. *Searching for medication adherence devices*. November 30 to December 2. Budapest, Hungary: 27th Annual Meeting of ESPACOMP, the International Society for Medication Adherence; 2023.
14. Morawski K, Ghazizadeh R, Krumme A, et al. Association of a smartphone application with medication adherence and blood pressure control: the MedSAFE-BP randomized clinical trial.

- JAMA Intern Med.* 2018;178(6):802-809. <https://doi.org/10.1001/jamainternmed.2018.0447>.
15. Gualtieri L, Wang D, Baek I. Reevaluating the utility of time-based reminders to increase medication adherence in older adults. 45th Annual Conference of Society for Behavioral Medicine; March 13-16, 2024; Philadelphia.
  16. Vervloet M, Linn AJ, van Weert JCM, de Bakker DH, Bouvy ML, van Dijk L. The effectiveness of interventions using electronic reminders to improve adherence to chronic medication: a systematic review of the literature. *J Am Med Inform Assoc.* 2012;19(5):696-704. <https://doi.org/10.1136/amiainl-2011-000748>.
  17. Ahmed I, Ahmad NS, Ali S, et al. Medication adherence apps: review and content analysis. *JMIR mHealth uHealth.* 2018;6(3):e62. <https://doi.org/10.2196/mhealth.6432>.
  18. Wang D, Gualtieri L. *Hosting a Co-Design Workshop: Older Adults Ideate Medication Adherence Solutions.* November 30, 2023-December 2. Budapest, Hungary: 27th Annual Meeting of ESPACOMP, the International Society for Medication Adherence; 2023.
  19. Gualtieri L, Shaveet E, Estime B, Patel A. The role of home medication storage location in increasing medication adherence for middle-aged and older adults. *Front Digit Health.* 2022;4. <https://www.frontiersin.org/articles/10.3389/fdgh.2022.999981>. Accessed October 19, 2023.
  20. Counterman ED, Lawley SD. Designing drug regimens that mitigate nonadherence. *Bull Math Biol.* 2021;84(1):20. <https://doi.org/10.1007/s11538-021-00976-3>.
  21. Kvarnström K, Airaksinen M, Liira H. Barriers and facilitators to medication adherence: a qualitative study with general practitioners. *BMJ Open.* 2018;8(1):e015332. <https://doi.org/10.1136/bmjopen-2016-015332>.