Telepresence as an Aid for Medication Self-Management

BY OLIVIA KAY HERNANDEZ, CAROLYN M. SOMMERICH, & DAVID D. WOODS

Stakeholder groups identify characteristics of a medication dispensing and monitoring device that could keep elderly people independent longer.

Tracy's mother was diagnosed with Alzheimer's a few years back. Her father passed away 2 years ago, and her mother has been living alone since then. Tracy is concerned that her mother is progressively getting worse, but she is unable to visit her mother often, as she lives more than an hour away. Tracy calls her mother weekly to check in, but her mother always says she is fine. Her mother's neighbor stops by every week to visit Tracy's mom, and recently called Tracy to tell her that her mother seemed to be having more trouble than usual remembering to take her medication. Short of making more visits or moving her mother into assisted living, Tracy is running out of ideas for how to make sure her mother is safe and able to care for herself.

This vignette is similar to one used for group discussions in a recent study concerning medication self-management (Hernandez, 2009). Many people like Tracy are concerned about ensuring their family members or friends are able to live independently. Medication self-management is just one aspect of being able to remain independent. How does one obtain information to check in on an ailing family member who lives far away? How can one determine if one's mother or father is able to be self-sufficient or needs additional support and assistance?

With so many technological innovations that can improve quality of life for the patient (the medication recipient), what can be done to improve a caregiver's ability to assess how well a patient is able to manage his or her medications, as well as other aspects of independence, to ensure the patient is able to remain on his or her own? The use of telepresence is one means that could greatly improve the capacity of caregivers to assess a patient's capabilities. *Telepresence* is the idea that an individual can be present in a setting without being physically present. There are many ways in which telepresence could ease the progression from independence to dependence of an elderly patient, provide peace of mind for caregivers, and enable caregivers to check on patients without having to travel. Telepresence promotes early detection of problems and could help keep people independent longer.

The Importance of Success in Medication Self-Management

Medication self-management is defined as one's ability to take medications as prescribed. Successful medication self-management leads to alleviation of symptoms, treatment of diseases, and other positive outcomes. When patients are unable to successfully manage self-medicating, complex and detrimental problems can occur. For older patients, it can tip the balance from aging in place toward the need to move to an assisted-living facility. Any complex system, such as health or health care, is highly interrelated and coupled; deficits in one area can cause negative effects in other areas.

One study reported that 5.5% of hospital admissions result from poor adherence to one's medical routine (Dowse & Ehlers, 2005), and another reported that up to 19% of hospital visits are related to medication nonadherence (Hayes, Larimer, Adami, & Kaye, 2009). Problems arise for both the community and individuals when people are unable to successfully self-medicate. Unsuccessful self-medicating can lead to increases in insurance prices, drug resistance from incompletely treated infections, medication waste (Ryan-Woolley & Rees, 2005), patient illness, and increased health care costs (Shrank, Avorn, Rolon, & Shekelle, 2007). It is estimated that drug errors and nonadherence issues cost between $50 billion and $100 billion

FEATURE AT A GLANCE: The goal of this article is to explore ways to keep elderly individuals independent longer and able to remain in their own homes. Caregivers — whether professionals, family, or friends — are an integral facet in enabling elderly persons to be independent. One of the most challenging aspects of maintaining independence is the complex issue of medication self-management. The main focus of this study considers how the addition of telepresence to a new and as-yet-undeveloped dynamic automated medication-dispensing device could help individuals self-medicate. Through telepresence, patients could easily be connected to a variety of caregivers.

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yearly in the United States alone (Dowse & Ehlers, 2005; Shrank et al., 2007). Ineffective treatments and ineffective analysis of treatments can occur if medications are not taken properly (Connor, Rafter, & Rodgers, 2004; Farris & Phillips, 2008). Nonadherence can result in serious complications leading to hospitalization and even death (Mackin & Arean, 2007).

For many older adults, taking medication successfully is an essential part of staying healthy or slowing declining health. Poor medication self-management can have a detrimental and permanent impact on the patient's independence, and preventing this negative impact is the driving force behind this study and line of inquiry. This study examined ways to improve the ability (a) of patients to successfully manage their medication regimen and (b) of caregivers to remotely assist the patient by providing ways for them to determine the current status of the patient and provide assistance if needed. A concept for the functional design of a new automated medication-dispensing device with telepresence capabilities is offered as a solution, accompanied by a list of functional requirements based on a literature review, discussion among the authors, and structured discussions with family caregivers, patients, and health care professionals.

Medication self-administration is a complex, multidimensional issue. In general, problems arise with self-medication when medication demands (therapeutic self-care) exceed the patient's abilities (self-care agency, Maddigan, Farris, Keating, Wiens, & Johnson, 2003). Using a systems approach toward the issue, one takes into account the specific illness, health systems, support systems, the patient, and other factors, and finds that all of these aspects play a role in the successful management of self-medication.

Typical Obstacles to Taking Medication

What makes successful management of medication challenging? After a review of the relevant literature, we identified 14 categories into which different factors and issues that affect self-management of medication were sorted:

- patient's personal beliefs and issues
- interruptions of life
- physical difficulties
- traits of the medication
- complexity of the medical regimen
- patient's cognition
- transportation concerns
- patient's finances
- medical instructions
- medication storage
- traits of the patient
- governmental issues
- traits of the disease
- presence of assistants or caregivers (Figure 1)

Providing means for addressing each of these factors will facilitate better medication self-management.

Existing Ideas to Aid Self-Medicating

All people, especially elderly persons, need to be able to self-medicate safely and effectively (Drummond, Drummond, & Dutton, 2004). Communication, patient education, and the use of aids such as medication cards are ways to address this issue (Kairuz et al., 2008). Cuing mechanisms and aids can provide an extra reminder or source of assurance that one's medications were taken.

One aid involves putting multiple medications into a single pill (fixed dose), and another option is to place multiple pills in a single blister pack (Connor et al., 2004). However, preparing individually tailored medication packs or schedules is time-consuming. Blister packs and security seals may pose problems for elderly patients because they must be able to open and store the package, as well as keep track of instructions that are not located on the packs. In addition, such packaging may not be widely available. Therefore, many elderly patients rely on pillboxes.

Use of a pillbox, however, does not ensure that the patient will remember to take the medication. Furthermore, pillboxes can be filled incorrectly. Using different colors of medication labels, icons or pictograms, and pill bottles with lids containing built-in sensors are all attempts at overcoming the inherent challenges in managing self-medication, yet all have deficiencies that limit their usefulness and practicality.

Several models of automated pill dispensers are available that assist with medication self-management. Whereas some are not much more than pillboxes with attached reminder alarms, others come with visual displays or mechanisms to prevent double-dosing of medication. Some dispensers can present auditory and visual text to aid patients in remembering to take medication or to remind patients whether medications have stipulations, such as needing to be taken with food or water. However, for some patients, trying to interact with a feature-laden device could cause more problems than would a simple pillbox. There can be challenges in understanding abbreviations used on the device, trying to set up multiple alarms for morning and evening, figuring out the various settings for an audible chime or vibration, and even remembering which pill was to be taken after hearing a specific alarm.

The presence of a caregiver as an aid can help patients to remember when to take their medications or whether they have already taken them. However, it may be difficult for a remote caregiver to provide real-time assistance to the patient, which could be problematic for maintaining a medication schedule or if there is an urgent medical matter. In summary, there are many challenges to designing any device that is intended to assist individuals with medication self-management; each of the aforementioned existing aids has shortcomings and limitations in its ability to assist patients with managing self-medication.

Recommendations to Aid Self-Medication

Medication self-management is one of the most important factors for patients' to be able to safely and adequately

Figure 1. Categories of factors affecting success in medication self-management.

take care of themselves. However, one must remember that adherence is a dynamic process and is subject to multiple interacting factors (Arlt, Lindner, Rosler, & von Renteln-Kruse, 2008). Today's automated medication-dispensing devices are capable of assisting on many level but still do not provide the dynamic and real-time interactions that some patients need.

To address existing shortcomings, a new medication-dispensing device is needed that is adaptable and flexible for the diverse challenges of everyday life in 21st-century cultures, wherein it is no longer the norm for extended families to live together and in which older individuals want to live on their own as long as possible. Such a device would necessarily have many functional requirements – aspects of the device that are essential for the machine to sufficiently function and provide assistance. The features provided by such a device could help patients achieve the goal of independent living while remaining safe. Quality of life would be retained and, potentially, improved because patients could live alone without feelings of worry or fear related to managing medications. The cost of health care would possibly decrease because fewer patients would require care in hospitals or nursing homes. There would also be more peace of mind for everyone involved in the patient's well-being, including the patient himself or herself.

What Would a New Medication Self-Management Device Have To Do?

To develop a list of functional requirements for this novel medication-dispensing device, we conducted a pilot discussion session, followed by six structured, small discussion groups. Both caregivers and patients who would use the machine participated in the discussions. The discussion groups included a medical doctor, a psychologist, two nurses, a pharmacist, the owner of a company that helps older adults manage their finances, a psychoanalyst, six individuals who manage their family members' medication, and 10 older adults who would be potential users of such a device. The older adults lived in an assisted-living facility, and some mentioned that they had struggled with opening packages and

taking medication. These older adults were a good representation of the types of patients who would benefit from the use of such a device. Some discussion group participants fell into more than one category and so have been listed twice, as they gave input from multiple perspectives. In all, 19 participants were included in the pilot and small discussion groups.

We told the participants that the main goals of the discussion were not to come up with the final look or functionality of the device but to consider what aspects and characteristics of such a device would prove useful to assist individuals to successfully self-medicate. This would assist the authors in developing a comprehensive and forward-looking list of functional requirements for the machine, and to uncover situations that make medication self-management challenging.

Discussion group members started with a warm-up and envisioning activity wherein they were presented with scenarios to get them thinking about what an automated medication-dispensing device would have to do to be useful. The second section of the discussion dealt with the concept of telepresence and how the medication-dispensing device would be able to remotely connect people while creating situational awareness and contextual sensitivity. The third section pushed the concept of telepresence further and allowed participants to imagine a particular scenario in which a health care practitioner, a family member, and the patient were discussing a potential change to the patient's medication through the device.

Findings from these discussion groups, along with ideas and concepts gathered from a review of related literature and discussion among the authors, were synthesized into a list of functional requirements. Each requirement is presented in the table starting on page 19 along with the logic supporting the inclusion of the requirement, a criticality rating, a rating of where the requirement fits within the scope of the vision for the device, and a time horizon for the requirement. The "Support for Requirement" column in the table provides a blend of comments and ideas from different sources as a basis for the functional requirement.

With telepresence, being "present" means being able to interact with the patient and to share that person's mental models and mindset.

The criticality rating for the different functional requirements relates to the main objective that the device's functionality assists patients with medication self-management. There are three levels of criticality: *critical, important,* and *useful.* Critical requirements allow the machine to fulfill its basic function, important requirements allow the machine to be more adaptable and flexible, and useful requirements are those that are not necessary for the machine to work but provide a practical service.

The functional requirements are also categorized into different scopes. The *core* scope includes concepts that relate to the direct function of the machine in aiding the patient. The *broad*-scope concepts relate to the interaction of the patient or the machine with family members, caregivers, and health care specialists. The *broadest*-scope concepts go beyond the stakeholders immediately linked to the patient, such as third-party service providers (see Figure 2).

Finally, the functional requirements are given a *short-term* or *long-term* horizon. The amount of time and level of complexity of the implementation of the requirement were the basis for determining whether the requirement was short or long term. Short-term concepts can be easily and quickly incorporated into the device. These features might not encompass all of the desired capabilities of the machine, but they do provide some value to potential users. Long-term concepts are more complex and challenging. They are not necessarily available yet and may have to wait for technological advances or additional infrastructure. As such, for realization of the first generation of this new device, key features will have to be prioritized to ensure that a preliminary device with sufficient functionality is created.

Distinctive Attributes of the Design for a New Medication Self-Management Device

Important aspects of this novel device would include allowing patients to remain independent longer, keeping caregivers informed of the patient's current status, allowing improved continuity of care, facilitating improved response to the dynamic nature of health, and improving quality of life. A unique feature of this new concept for a patient-centered medication-dispensing device would be an interface that provides telepresence for a caregiver to monitor, or check on, the patient remotely. Telepresence provides a backup when the machine's built-in, on-the-scene knowledge is too limited to adequately aid the patient. With telepresence, being "present" is not limited to simply having a view into the space; it means being able to interact with the patient and to share that person's mental models and mindset, to understand the current situation in depth, and to notice trends and patterns that can help diagnose problems.

Telepresence also provides context for the caregiver to be able to resolve ambiguities and to provide tailored help. Through telepresence, caregivers can address questions from their care recipient about current challenges regarding their medications. Motivation to take medication is related to the kind of mental model the patients have formed of their disease and of how the medication plays a part in regulation of the illness, and with telepresence a caregiver could analyze the patient's motivation from a distance (Klein & Meininger, 2004). Caregivers could also remotely check their care recipients' health status and pattern of medication administration to confirm success or detect problems promptly. This capability of the machine helps to mitigate risks inherent with elderly persons living alone.

The new device would allow both synchronous and asynchronous interactions. It would be flexible with regard to who could initiate interactions, and could initiate those interactions when the patients need them most. For example, take the functional requirement of being able to get a quick, generalized view of the patient as well as an in-depth view. For the quick overview, a remotely located family member could be presented with a spreadsheet or special alert that tells him or her if the patient missed a pill. If the family member then wanted to follow up and ask whether the patient is feeling ill or if the patient has been forgetting things lately, the family member could call the patient through the device and talk with him or her.

The functional requirements of having communication abilities, the ability to monitor the patient, and the ability to update family members and caregivers each has the same flexibility of providing synchronous or asynchronous interactions. The functional requirement of communication refers to the provision of live audio and video and the enabling of informative patient-caregiver interactions, which afford a richer exchange of information than provided via a one-way "monitoring" system.

The functional requirement of increasing the patient's knowledge about his or her medication is also both synchronous and asynchronous, but in a different way. The device could immediately show the patient that he or she has missed a pill by having the pill visible in the dispensing dish and through the interface. However, the patient could also see whether he or she has been missing pills by looking back through device-generated reports. This ability of the device would encompass the functional requirements of easily indicating missed doses, ensuring that medication was taken, and dynamic scheduling of medication.

Summary

We consider this inquiry to be essential preliminary work for the design of a new and more effective generation of medication-dispensing devices, ones that will be equipped with smarter automation and telepresence. Through the group discussions, it was demonstrated how telepresence and user-centered design could be utilized in the future to mitigate risks for patients living independently and to allow caregivers to remotely assess and assist the patient. This study's aim was to determine the necessary functional requirements for a novel, dynamic medication-dispensing device that would be viewed as useful, usable, and desirable by patients and their remotely located caregivers. There is great need and opportunity for such a device, given the current state of existing aids and the growing need for assistance with medication self-management as baby boomers age and families remain scattered.

The addition of telepresence to the device is what will endow it with a significantly increased measure of flexibility and adaptability. This device would help a variety of caregivers (family members, home health care nurses, pharmacists,

Functional Requirements Of A Medication-Dispensing Device

Functional Requirement (refer to footnote for letter designations)	Support for Requirement	Criticality to Fulfilling Device Goals (author's perspective)			Scope (author's perspective)			Time Horizon	
		Critical	Important	Useful	Core	Broad	Broadest	Short	Long
Dynamic scheduling[b]	If a patient drops, loses, does not take, skips a pill, etc.	✓				✓		✓	
Communication through telepresence capabilities like audio and video[c]	Telepresence "speed dials," updates, calls caregivers, facilitates support groups	✓				✓			✓
Updating family and caregivers[c]	Determines when refills are required, changes in schedule if patient misses pills, notes changes in symptoms	✓				✓		✓	
Increasing patient knowledge[c]	Machine knows side effects, interactions, images of pill	✓				✓		✓	
Ease of patient interaction[c]	Straightforward, simple, patient-centered	✓			✓			✓	
Easily indicate missed doses[d]	So both patients and caregivers can easily determine	✓				✓		✓	
Telepresence[d]	Remotely checks-in on patients in-depth, accelerates information flow, context sensitivity	✓					✓		✓
Separated pill filling area inside machine[d]	Dispenses pills, issues refill reminders	✓			✓			✓	
Dispensing mechanism[d]	Delivers medications to patient	✓			✓				✓
Holding tank for improperly dispensed pills[d]	Keeps pills that are improperly dispensed from being given to patient, if pills are dispensed but are not taken	✓			✓			✓	

(continued)

FUNCTIONAL REQUIREMENTS OF A MEDICATION-DISPENSING DEVICE (continued)

Functional Requirement (refer to footnote for letter designations)	Support for Requirement	Criticality to Fulfilling Device Goals (author's perspective)			Scope (author's perspective)			Time Horizon	
		Critical	Important	Useful	Core	Broad	Broadest	Short	Long
Interface of machine[d]	Displays patient requested and other data, telepresence portal	✓					✓		✓
Battery back-up to AC power[d]	For power outages, travel, etc.	✓			✓			✓	
Daily machine generated report[d]	Updates stakeholders and catalogs data	✓				✓		✓	
Monitoring[c]	Biofeedback wristband, nursing staff, supports taking pills in different places, records missed pills, verifies pills were taken		✓				✓		✓
Ability to have general and detailed views of patient[c]	Visual display gives more details, notifications give quick summaries, telepresence allows detailed interactions		✓		✓			✓	
Taking pills away from main machine[b]	Addresses situation where patient is not always at home		✓		✓			✓	
Appropriate number of alarms[d]	Provides flexible schedule		✓		✓			✓	
Little physical dexterity needed[d]	Facilitates pill-taking for patients with reduced manual dexterity and strength		✓		✓			✓	
Size and portability of machine[d]	Machine needs to be small and light enough to move		✓		✓			✓	
Machine can read medication labels for information[d]	Machine determines schedule, knows side effects, recognizes interactions		✓		✓				✓
Cost[d]	Cannot be too expensive so all patients can afford		✓		✓				✓
Ensuring medication was taken, check if any pills were left behind[d]	Software determines if pills were taken		✓			✓		✓	✓

Functional Requirements Of A Medication-Dispensing Device (continued)

Functional Requirement (refer to footnote for letter designations)	Support for Requirement	Criticality to Fulfilling Device Goals (author's perspective)			Scope (author's perspective)			Time Horizon	
		Critical	Important	Useful	Core	Broad	Broadest	Short	Long
Variety of alerts and alarms[d]	Can be personalized for hearing loss, etc.		✓		✓			✓	
Alerts and alarms for nonpill or over-the-counter medication[d]	Reminds patient of other medications		✓		✓			✓	
Machine maintenance[d]	Enhances accurate medication dispensing		✓		✓				✓
Voice recognition software[d]	Answers patient queries and requests		✓		✓			✓	
Ability to control amount of data patients see[d]	Lessens patient's confusion and sense of being overwhelmed			✓		✓		✓	
Pause button for alarms[d]	For use if patient is busy			✓	✓			✓	
Trusting the machine[a]	The machine is presented with a social face			✓	✓				✓
Easy and safe way to refill machine[d]	No lock and key required			✓	✓			✓	
Wristband to activate camera and dispensing[d]	Patient activates machine; machine issues redundant alerts			✓	✓			✓	

a. Suggested in a single discussion group.
b. Suggested in a single discussion group and by authors.
c. Suggested in multiple discussion groups and by authors.
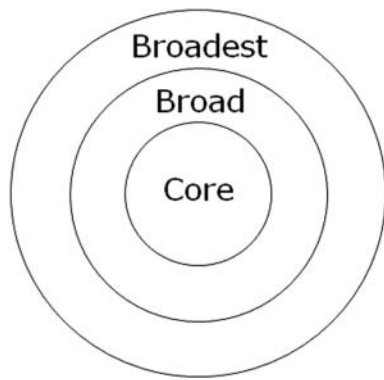d. Suggested by authors.

Figure 2. Visualization of scope designations.

References

Arlt, S., Lindner, R., Rosler, A., & von Renteln-Kruse, W. (2008). Adherence to medication in patients with dementia: Predictors and strategies for improvement. *Drugs & Aging, 25*, 1033–1047.

Caine, K. E., Fisk, A. D., & Rogers, W. A. (2006). Benefits and privacy concerns of a home equipped with a visual sensing system: A perspective from older adults. In *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting* (pp. 180–184). Santa Monica, CA: Human Factors and Ergonomics Society.

Connor, J., Rafter, N., & Rodgers, A. (2004). Do fixed-dose combination pills or unit-of-use packaging improve adherence? A systematic review. *Bulletin of the World Health Organization, 82*, 935–939.

Demiris, G. (2009, September). *Privacy and social implications of distinct sensing approaches to implementing smart homes for older adults.* Paper presented at the 31st Annual International Conference of the IEEE EMBS, Minneapolis, MN.

Dowse, R., & Ehlers, M. (2005). Medicine labels incorporating pictograms: Do they influence understanding and adherence? *Patient Education and Counseling, 58*, 63–70.

Drummond, S. R., Drummond, R. S., & Dutton, G. N. (2004). Visual acuity and the ability of the visually impaired to read medication instructions. *British Journal of Ophthalmology, 88*, 1541–1542.

Farris, K. B., & Phillips, B. B. (2008). Instruments assessing capacity to manage medications. *Annals of Pharmacotherapy, 42*, 1026–1036.

Hayes, T. L., Larimer, N., Adami, A., & Kaye, J. A. (2009). Medication adherence in healthy elders: Small cognitive changes make a big difference. *Journal of Aging and Health, 21*, 567–580.

Hernandez, O. K. (2009). *The next generation of medication dispensing devices.* Unpublished master's thesis. The Ohio State University, Columbus.

Kairuz, T., Bye, L., Birdsall, R., Deng, T., Man, L., Ross, A., . . . Tautolo, E. (2008). Identifying compliance issues with prescription medicines among older people: A pilot study. *Drugs & Aging, 25*, 153–162.

Kleiboer, A., Gowing, K., Hansen, C. H., Hibberd, C., Hodges, L., Walker, J., . . . Sharpe, M. (2010). Monitoring symptoms at home: What methods would cancer patients be comfortable using? *Quality of Life Research, 19*, 965–968.

Klein, H. A., & Meininger, A. R. (2004). Self management of medication and diabetes: Cognitive control. *IEEE Transactions on Systems, Man and Cybernetics, Part A–Systems and Humans, 34*, 718–725.

Mackin, R. S., & Arean, P. A. (2007). Cognitive and psychiatric predictors of medical treatment adherence among older adults in primary care clinics. *International Journal of Geriatric Psychiatry, 22*, 55–60.

Maddigan, S. L., Farris, K. B., Keating, N., Wiens, C. A., & Johnson, J. A. (2003). Predictors of older adults' capacity for medication management in a self-medication program: A retrospective chart review. *Journal of Aging and Health, 15*, 332–352.

Ryan-Woolley, B. M., & Rees, J. A. (2005). Initializing concordance in frail elderly patients via a medicines organizer. *Annals of Pharmacotherapy, 39*, 834–839.

Shrank, W., Avorn, J., Rolon, C., & Shekelle, P. (2007). Effect of content and format of prescription drug labels on readability, understanding, and medication use: A systematic review. *Annals of Pharmacotherapy, 41*, 783–801.

etc.) in aiding patients who are living independently. Especially for individuals who do not have someone who regularly stops by to check on them, this device would have to be able to address a variety of problems and circumstances that cannot always be predicted. The device's built-in functionality would provide it with one boundary, or set of constraints and limits, that would enable it to address the majority of encountered difficulties, while the telepresence would provide a second, wider boundary that would encompass more than the device could handle on its own, thereby greatly enhancing its usefulness for patients and their caregivers compared with any medication management aids currently available.

The next steps in this line of inquiry to assist older individuals with their variety of needs and levels of ability with respect to medication self-management involve additional research groups, the development of a prototype, hands-on testing to determine whether the device meets the needs of all stakeholders, and full-fledged testing with the device placed in patients' homes. These steps would also help resolve some of the limitations of this study (for example, we did not focus on the interface from the caregiver's perspective). The administration of liquid, injected, and inhaled medication also has not yet been addressed. Whether patients would view the device as a form of home monitoring, and how receptive or resistant they would be, requires further exploration.

Prior relevant studies show that older individuals do not have a predisposition against telemedicine interventions and that their degree of acceptance is related to several factors, including perceived health benefits, extent to which the monitoring serves a specific purpose, usability of the equipment, and personal characteristics of the patient (Caine, Fisk, & Rogers, 2006; Demiris, 2009; Kleiboer et al., 2010).

In closing, it is critical to apply human factors/ergonomics principles to the design of health care products, services, and systems to continue the transition to a more user-centered perspective, which has been shown to reduce errors, increase patient safety, and improve overall health outcomes.

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