HOME HEALTH MONITORING
An in-depth look into designing the next generation of health technology for older adults living at home

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Dedicated to my grandparents, living and remembered

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Abstract

The changing landscape of healthcare regulation, shifting needs of an aging population and recent growth in the digital health marketplace have placed home health monitoring and its associative technologies at the forefront of discussion for both consumers and companies. Organizations across the country are looking to identify the next big breakthrough in the healthcare industry and capitalize on sizable gains in investment. However, there remains significant disparities between the goals of the industry and the fragmented solutions currently available. This paper utilizes literature research, stakeholder interviews, company comparisons and an evaluation of the regulatory environment to build a robust framework from which to structure future innovation in the digital home health monitoring space. Findings indicate that by engaging key stakeholders (patients/informal caregivers/providers) and attending to their top needs (social engagement/care-life balance/treatment adherence, respectively) through the use personalized, communicative, and integrated designs, home health monitoring technologies can have substantial value at the industry level. Specifically, products that address informal caregivers’ challenges associated with managing medication for older adults by building strong cross-stakeholder relationships through communicative means are likely to have the greatest impact in the next 5-10 years.
Background

The next generation of leaders in the healthcare industry are confronted with an increasingly complex and nuanced health system. Not only do patients and clinicians now demand better experiences, the industry must also deliver improvements to the health of the entire population, all at a lower cost.\textsuperscript{1} To add to the dilemma, the US population will shift dramatically over the next few decades; from 14.7\% over the age of 65 in 2015, to nearly 21\% in 2035.\textsuperscript{2} This will significantly impact the way healthcare is delivered. Technology is now also inextricably linked to every-day life, and the rate at which we depend on the services dispensed through it is continuing to accelerate. Finding solutions to address the healthcare needs of this new, technologically savvy generation (and the generations to come) is paramount to the success of the industry, not to mention, the long-term sustainability of the economy and well-being as a species.

Telemedicine and Home Health Monitoring

Telemedicine is considered by many as the next generation of healthcare delivery models, especially for rural areas with limited access to specialty or even basic healthcare. With the availability of faster internet connections, smartphones, and new, advanced data protocols (ie. Bluetooth 5 was debuted in 2016 in London), effective telemedicine is more feasible than ever before\textsuperscript{3}. Doctors can now use live video streams and web-based care coordination networks to share information and deliver high-quality care, regardless of the location. Additionally, patients have the opportunity to utilize new, high-tech devices to monitor health indicators (ie. heart rate, blood pressure, etc.) from home and send this data to their care provider for analysis. Telemedicine is a rapidly changing, expansive piece to an already

\textsuperscript{1} Bodenheimer, Thomas; Sinsky, Christine. (2014). \textit{From Triple to Quadruple Aim: Care of the Patient Requires Care of the Provider}. Annals of Family Medicine. Vol 12-6. pp 573-576
complex industry. This paper, focuses on a subset of telemedicine known as home health monitoring, specifically, digital systems designed for older Americans living at home.

A home health monitoring system can support live clinical metric tracking, reinforce patients’ direct interaction with primary caregivers (formal and informal), and improve patients’ engagement with the overall healthcare experience. The idea is simple in nature: more patient engagement leads to increased accountability and interaction which in turn improves outcomes and overall quality of life. However, executing this type of system effectively is complicated. The success of the system is highly dependent on its design (including technical components and consumer interface), its intended users, and the purpose it hopes to accomplish. These advanced systems must also cater towards the unique needs/desired specifications of each type of “user” (ex. an elderly patient with chronic obstructive pulmonary disease, an assisted living facility nurse, a primary care physician, a family caregiver) without marginalizing certain groups.

New monitoring systems brought to market do not effectively study how design, users and underlying purpose align to create an impactful outcome to both the patient and the caregiver, be it a family member or healthcare provider. Research into the coordination of such systems is not available and there remains a significant need to conduct larger studies using controlled interventions which focus on the patients’ perspectives and economic analysis. In spite of these gaps, most academics agree the evidence for the value of home health monitoring systems is promising, albeit incomplete.

Limitations and Barriers

There are three main components to any web-based home health monitoring system: measurement and data collection, information transmission and security, and usability. Each

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monitoring system has its own set of strengths and may excel at one or two, but rarely all three. For example, by increasing the clinical data capturing power of a system, you inadvertently decrease its usability as more complex measurement usually requires a larger, more sensitive system.

Balancing these strengths is hindered by a variety of barriers. With higher quality data comes greater restrictions placed by government regulation on how it can be stored and transmitted, usually increasing costs and unwillingness of caregivers to purchase the system and integrate it into their already complex IT network (ie. hospitals). Although new incentives are constantly introduced by governmental programs to encourage innovation, the costs associated with implementing new technological solutions outweigh any measureable benefits or savings.

Higher quality data also does not necessarily equate to more descriptive information to use for actionable decision making. Data can be marred by erroneous measurements or indicators that may influence healthcare professionals to incorrectly recommend care. Not only is this true in the home setting, but also at clinical institutions. False-positives have been shown to exceed 68% in pediatric intensive care units, despite the fact that dedicated teams of technicians and engineers constantly examine and adjust the equipment to be as consistent and accurate as possible.\(^6\)

For this reason, many providers are reluctant to administer medical advice based on data generated by systems they cannot monitor or do not know if they have been adequately calibrated. If their recommendation to a patient resulted in injury, the doctor may be liable by the way of negligence, even if they interpreted the data correctly and acted in accordance with normal procedure. These kind of challenges make it difficult to assemble a system with clinical significance without overburdening the

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patient or caregiver and can contribute to the resistance of adoption and implementation by the healthcare industry as a whole.

Another barrier is the conflict of interests between the different groups of “users”. For example, a doctor may get a lot more information from a patient wearing a full EKG all day, but it will likely restrict the patient’s ability to move about their home freely. Conflicts also arise from personal/cultural preferences, socioeconomic status, health literacy/education, and other external influences. What works for an urban-based, highly educated family caregiver may not work for an elderly grandparent in a rural setting. Understanding how these aspects affect (and are affected by) the final design of the system can ultimately determine its success.

Designing for the End-User

One way to limit conflicting design interests is to target certain patient characteristics such as cognitive/physical ability, chronic/comorbid conditions and various demographic factors. With greater specificity, a system can more accurately track data and present meaningful reports to the intended recipient and feedback to the user. The “graying” of the modern world has put older adults in the spotlight as they are a key stakeholder in the potential growth of these types of systems, especially given their increased interest in technology and personal autonomy. However, targeting the “elderly” is not enough. Within this group there exists a range of additional sub-groups: from the healthy, energetic elderly who are mobile, independent, and sociable, able to access the health system without assistance; to the sick, frail and solitary, sequestered into long-term care facilities.7 The needs of these sub-groups differ drastically, including unique considerations such as:

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• Does the user have any significant risk factors, such as chronic conditions, a recent hospitalization, tobacco use, or problems with obesity? Where were they last discharged? How often do they access the healthcare system and what is the nature of their interaction?

• What is the user’s relationship(s) with their caregivers? Are they alone? Is their family actively involved with their care? Do they have a network of other informal caregivers?

• What is the nature of the user’s surrounding environment? Are they in a rural or urban area? Do they live in an elderly-focused community? Does their home have more than one level and how often do they leave their home?

It is important to keep in mind that older adults can be unreceptive of new technology, especially if it is not user friendly, requires significant training, or lacks a human response.8 Answering these questions and addressing the issues identified allows the system to focus its purpose and goals, potentially increasing the uptake and impact it can have on the user’s health.

Another way to center the design of the system is to place an emphasis on particular disease states. A sizable portion of research has shown that evidence is lacking for using smart home and home health monitoring technologies to address disability prediction, health-related quality of life, and fall prevention.9 Contrarily, home health technology has shown to be effective in monitoring daily activity, cognitive decline, mental health, and certain heart conditions. Concentrating on the areas with proven advances in outcomes increases the marginal value of home health monitoring systems and will likely have a significant effect on the consumer perception and marketability of these systems.

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A well-defined end-user allows a system to be highly tailored. However, at a certain point, there are diminishing returns as further specifying limits the size of the impact (and potential market) a system could have. Again, a balance must be struck between what the system hopes to accomplish from both discrete and general perspectives. An ideal system would include ubiquitous mechanisms that have wide appeal, yet at the same time, have the ability to be customized to each individual situation.

A Changing Industry

There is still a significant amount of debate regarding the impact of telemedicine on clinical outcomes.\(^4\) Studies are beginning to show that certain therapeutic interventions seem to benefit from telemedicine more than others, but results remain inconsistent. What is known is that the growth of wireless technology and advanced data networks will continue to reshape the design and delivery of healthcare in the US and around the world.

Specific Aims

The purpose of this paper is to evaluate the design specifications for digital home health systems which promote healthy behaviors and lifestyle choices among the aging population living at home, specifically, those receiving care from informal caregivers (ie. family members). Web-based, voice-controlled, active feedback systems integrated with a customized network of sensors may have a positive effect on the well-being of users (including providers, patients and caregivers) by improving certain health-related measures and the overall care experience. Thus, the project’s aims fall under three main categories:

1. Evaluate which problems identified by informal caregivers can be effectively managed by a home health monitoring. What are the most important issues to address for providing care to the elderly living at home?
2. Identify which behavioral (and clinical) health indicators are most tightly correlated with having a positive effect on the problems as defined in #1. What needs to be measured to determine a successful intervention?

3. Determine which tactics can be employed by internet-linked, voice-controlled smart home systems to impact the behavioral measures identified in #2. What interventions are possible given existing hardware and software technology?

**Significance**

Although the aims are written in a linear fashion, they are inextricably linked and iterative in nature; aim #3 limits the scope of the possible solutions to the problems recognized in aim #1. Accomplishing the aims set out above prepares a framework of the ideal system that could be built using existing hardware and software. This can then be extrapolated to a full-fledged business plan and go-to-market strategy. The framework is also structured in a way to adjust to changes in technology and the market so additional capabilities and clinical capacity can be added as remote monitoring devices proliferate and become more reliable. The overarching goal of this project is to explain the role digital home health monitoring systems could play in the consumer market and the value these types of systems present to older adults, care providers and potentially healthcare systems.

**Methods**

This study employed largely qualitative methods to accomplish the aims laid out above including an examination of peer-reviewed literature, stakeholder interviews, competitive market analysis and regulatory evaluation. Although primary data collection would be desirable for confirming some of the assumptions made, it was considered out of scope as this would require a working prototype, IRB approval, a sizable test population, and substantially more time. Furthermore, given the recent growth in the home health monitoring market over the past two decades, there was limited value to be
garnished from primary data collection outside of what was already established in peer-reviewed literature, unless a new prototype design was to be tested. Through coalescing the findings from each category of research, feasible strategies, realistic conclusions and future steps were defined.

Literature Review

Recently, research into telemedicine and home health monitoring has grown substantially due to the increased pressure from the healthcare industry to find solutions to the quadruple aim (cost, access, quality, coordination). New studies cover a broad swath of topics associated with this field, including: system architecture and design; user perception and technological acceptance; specific conditions, devices, demographic groups and behaviors; and general data reliability and industry-level trends. What these articles fail to accomplish is a synthesis of the results across them to formulate a compelling argument for targeting a particular population or design, the main motivation for this report.

Stakeholder Interviews

Assessing the likelihood of acceptance of home health systems by all of the associated stakeholders is vital to success as a business. Interviews conducted of industry experts, company executives, and formal/informal healthcare workers provided a well-rounded perspective on how new home health systems could have a positive impact and what components were the most critical to include. End-users/patients were also interviewed to get a better grasp on their perception of home health systems. This group frequently shared opinions that were consistent throughout.

Competitor Analysis

Understanding the current market is essential for determining improvements. Few systems that exist have drastically changed how care is delivered or demonstrated verifiable benefits to the stakeholders and industry. By examining technologies and services available, top performers were identified and compared to determine similarities and differences. This highlighted which design
elements/features were consistent across solutions and simultaneously pinpointed gaps to focus future innovation, setting the course for new products under development.

**Regulatory Evaluation**

To be a successful company in the healthcare market, regulatory underpinnings must be considered. This includes examining legal implications of what constitutes as “standard of care”, financial incentives supported by government programs, and intense privacy laws associated with healthcare data. While this paper does not cover all nuances associated with healthcare IT and reimbursement, it inspected some of the key motivators, barriers, and pathways facing the home health monitoring (and telemedicine) marketplace. These insights established directions as how to structure new systems without constantly running into opposition from forces outside the realms of control.

**Conceptual Model**

To understand the conceptual model of a home health monitoring system, it is important to evaluate the network of healthcare information and communication both before and after a system is introduced. The two states are visually represented using the diagrams below (shapes represent stakeholders; arrows, interaction pathways):
Before

Informal Care Provider → Formal Care Provider → Patient → Healthcare Facility → Pharmacy

Informal Care Provider → Formal Care Provider → Patient → Healthcare Facility → Pharmacy

After

Informal Care Provider → Formal Care Provider → Patient → Home Medical Monitoring System → Pharmacy

Informal Care Provider → Formal Care Provider → Patient → Home Medical Monitoring System → Pharmacy
As demonstrated by the diagrams, using a home health monitoring system significantly reduces the complexity of the communication network as it serves as a conduit through which all information passes. Patients and informal caregivers experience the greatest reduction in effort as they no longer have to work with many independent channels simultaneously. The “After” diagram also incorporates advanced functionality into the system, such as automatic medication filling, personalized provider recommendations, and instant emergency services coordination.

Results

The trajectory of this project shifted as new insights were garnished and unexpected themes discovered. What began as a study of technical devices and systems became an in-depth look into the value consumer home health technology has in the larger healthcare environment. At a high level, professional (and informal) caregivers were determined to be less interested in discrete data associated with home health monitoring systems than initially thought. Although the accuracy and validity of information generated from clinical-grade consumer devices has improved in recent years, most stakeholders interviewed supported the notion that the data generated was less than useful. Caregivers indicated overwhelmingly they did not have capacity or desire to review and compare data.

This issue separates the digital home health monitoring industry into two separate value-delivery models: a service model where a dedicated group of healthcare professionals analyze data and offer advice to caregivers; and a tool/device model that improves the convenience and execution of the caregiving process. Many solutions on the market include elements of each, but this paper focuses largely on the latter model as it is more ubiquitous and easily evaluated. The following is covered in the subsequent sections of this report:

- The market for care accessibility related tools is defined
- Key design features required of all new technologies are described
Current obstacles and ways around them are explained

A final summary of the results is given in the conclusion, including how they were applied to two prototypes currently under development.

Defining the Market

By 2018, the consumer healthcare market is expected to grow to a value of around $700 billion. The jump is driven primarily by preventative health management products such as over-the-counter drugs, vitamins and fortified foods. Wearables and digital health technology make up a smaller piece of the market, but it is thought that digitally enabled consumers are a key component to spurring additional investment in this industry. With affluence, aging and coinciding chronic conditions affecting a larger portion of the population, consumers are now taking more active roles in managing their health.\(^\text{10}\)

To address the changing population’s needs, a variety of new products and services have entered the market in the hopes to simultaneously improve the quality of healthcare and fulfill customers’ new desires. This separates potential customers into two main groups: classically trained healthcare professionals who strive to administer the best possible treatment; and uninformed patients who rely on the healthcare system to receive the best possible care. For older adults and other patients needing more continuous care, a third, separate group exists, informal caregivers. Informal caregivers play a critical role in facilitating the care-delivery process and ultimately generating positive outcomes. In the next few sections, each user group is examined and a rationale is presented as to why informal

Providers

Unfortunately for healthcare professionals, making good on the promise to improve care through consumer digital health technology has proven to be difficult. Patients’ now unlimited access to data and information via wearables and the web may afford them greater awareness, however, this information’s value to providers is marginal and only further complicates the healthcare environment. According to Piwek, et al, “less than 5% of surveyed health care providers felt that any Internet self-diagnosis was helpful.”\(^{11}\) Additionally, patients without medical training who bring wearable data and internet-based research to consultations often attribute symptoms incorrectly and are more likely skeptical of recommendations from their care provider. These concerns combined with the aforementioned issues surrounding device accuracy, limited resources, and legal risk make home health monitoring systems a hard sell for healthcare providers and systems.

One way to encourage provider acceptance of home health monitoring is to address the issue of medication adherence, a central pain point for providers. Of every 100 prescriptions written by doctors, only 25-30 are taking properly by the patient.\(^{12}\) Adherence tends to decline over time, especially if there are side effects or no noticeable benefit. This frequently can lead to hospital readmissions, longer stays in the hospital or other costly procedures that impact both the provider and patient.\(^{13}\) Medication reminders administered through home health technology are one way to reduce the chances of non-


adherence.\textsuperscript{14} Improving patients’ understanding of treatment regimens through care plans and adherence monitoring are another.\textsuperscript{15,16} Caregiver support also helps patients remain adherent.\textsuperscript{17} Clearly, home health monitoring opens several paths to improving medication adherence in older adults.

Despite resistance from the clinical community, health monitoring gadgets continue to be popular amongst consumers as a trendy way to be “knowledgeable”\textsuperscript{11}. Providers now need to prepare for the overly informed patient, but also look for ways to make the patient’s desire for engagement support treatment adherence and positive outcomes. Additionally, while healthcare professionals may not be the main purchaser of such systems, they impart important inroads into the growth and validity of new technology entering the marketplace. By using technology to increase patient understanding and and improve adherence to treatment plans, providers may find value in these products still.

\textit{Patients}

Patients, also known as care recipients, exist on the opposite end of the care spectrum yet surprisingly are as disinterested in purchasing home health technology as their provider counterparts. Even though most of these systems are meant to improve care recipients’ quality of life and health outcomes, few patients understand how this is accomplished or why it matters.\textsuperscript{18} This is particularly true for older adults. Interviews and studies suggest that older adults see automation and monitoring as potential impediments to meaningful social interactions, something the value highly.\textsuperscript{8} Convincing this

\begin{itemize}
\item \textsuperscript{18} Mann, W. C.; et al. (2007). \textit{Older Adults' Perception and Use of PDAs, Home Automation System, and Home Health Monitoring System}. Topics in Geriatric Rehabilitation. Vol 23-1. pp 35-46.
\end{itemize}
group that a new tool or system could make their lives better requires demonstrating that the change would have a positive impact not only on them personally, but their surrounding community as well.

Interestingly, older adults subjected to new monitoring systems are less concerned with privacy and information security than commonly perceived. As long as systems do not impede the care recipient’s autonomy, they have little apprehension over who is watching over them. Research also shows perceived social benefit is only reinforced the longer older adults use monitoring technologies. These two facts underscore two important elements of success for new health tech ventures: companies must engage their target users early in the product development lifecycle; and they must clearly convey what their solution does and why the care recipient should care. Once bought-in and aware of the benefits, care recipients are lifelong supporters.

It is estimated that four out of five adults in the US over the age of 50 (about 70 million people) suffer from at least one chronic condition. Those over the age of 65 spend more than twice the amount per person on healthcare when compared to younger US citizens. Finding a way to engage this group and address their health needs will be extremely financially lucrative. However, in spite of these advantages, connecting with older adults entails more than just asking what they want or how they can be helped. To reach this group, companies need a different approach; the conduit for access are the informal caregivers who support their aging loved-ones.

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Caregivers

All informal caregivers have several key aspects that make them the ideal candidate for targeting new digital health innovation. First, they supply over 90% of care to the incapacitated elderly in the US and 66% of older people with disabilities receive all their care from family caregivers (for long-term services and support).\textsuperscript{23,24} 50% of older adults with chronic conditions (about 34 million people) receive about 19 days of unpaid care each month, which is estimated to have a value of approximately $470 billion.\textsuperscript{25} This places enormous time and financial burdens on families as they often give up income or change their living situation to accommodate. Unforgivingly, the number of hours dedicated to caregiving increases with the caregiver’s age, which is especially true for older caregivers looking after a spouse or partner.\textsuperscript{25} Due to the depth and breadth of tasks completed, caregivers interviewed stressed the importance of incorporating convenience into digital health systems and were amicable to using products that did this effectively.

Next, caregivers are typically younger than their care recipients, making them more accustomed to a technology-savvy society and thus willing to try new digital solutions aimed at lightening their load.\textsuperscript{25} Informal caregivers are often a user of the technology and once the value of a new tool is validated by them, getting the patient on-board is much easier. Care recipients trust the recommendations of their family and friends more than any other member of their social network, including providers. By establishing a strong relationship with the informal caregiver, companies inadvertently do so with the patient population they hope to impact.

Informal caregivers also often control the finances for the care recipients they support.\textsuperscript{25} This is in part to ration funds as their loved-ones age, but also to make sure any new investments in housing, lifestyle, and/or care support provide the largest benefit to all parties involved. Additionally, caregivers’ close connections to the formal care environment, including health insurers and providers, make them intimately involved in all decisions made by and on behalf of the care recipient. Frequently having legal powers of attorney, caregivers hold the keys to new users buying-in or opting-out.

Most importantly, informal caregivers are more motivated to deliver the best care experience possible than any other stakeholder. This is simply because they have a relationship with the care recipient that (usually) transcends any monetary gain. In other words, they love their care recipient; they want that individual to have a happy and healthy life and will go through any means to accomplish this. This emotional currency may not be easily quantifiable, but it is the caregivers’ goodwill that will make or break new health monitoring systems entering the marketplace.

Informal caregivers are both the lead decision maker and the most impacted by home health monitoring systems. This fact and the challenges associated with the other groups makes them a vital customer for new digital home health technologies. Although the individual needs of caregivers and their associative care recipients differ depending on physical/cognitive ailments, socio-economic status, geographic location and other factors, informal caregivers can be universally labeled as the “gatekeepers” of care for older adults in the US. The next section of this report identifies which design aspects are the most significant to this group and, concurrently, providers and patients.

Key Design Features

Home health monitoring technologies address a wide range of issues facing caregivers and care recipients. From highly specialized clinical measurement tools, to low-impact intelligent personal assistants, a different device or system exists for each individuals’ unique needs. New studies are now
beginning to verify the reliability of clinical data generated by home monitoring devices, particularly those measuring pulse through wrist/finger oximeters. Other, consumer-grade devices, such as the FitBit® and Jawbone®, have less diagnostic power (heart rate data is extrapolated from measuring steps via an accelerometer), but their low price points and availability on the marketplace make them attractive to more consumers. Therefore, the challenge facing many patients and their caregivers is identifying which product best matches what they hope to accomplish with the home monitoring system.

In recent years, the number of home health technologies available on the market has increased substantially. This is in part due to the improved bandwidth and processing power of miniaturized devices, data networks and sensors, but also because of the availability of digital devices. With 64% of American adults owning a smart phone and 62% of smartphone users looking up health conditions on their phone (the largest segment of use after calling/texting/basic internet browsing), it is no wonder that new ventures see home health systems playing a pivotal role in the consumers of the future.

Even though health-related technologies span a swath of features, three consistent themes were seen throughout all of the products evaluated. These are:

- Using integrated resources to generate statistically significant outcomes which impact a larger audience of users.
- Incorporating personalized user experiences and interactions to encourage engagement and adherence to interventions

• Reinforcing communication channels between patients, caregivers and providers to build meaningful relationships and practical treatment plans

Products that highlighted these features more aptly were generally seen to be more successful, both from health and financial perspectives, than those with limited understanding and/or execution on these characteristics.

Integration

Industry-wide integration is the first fundamental step for all successful home health systems. Not only is this necessary for generating meaningful insights and building relationships across the care continuum, it is the future of the healthcare industry. The birth and evolution of the electronic health record (EHR) is a testament to this movement, with companies such as EPIC topping $1.7 billion in revenue in 2014. Furthermore, providers reimbursed by Medicare and Medicaid must now demonstrate “meaningful use” with their EHR to avoid penalties. As the industry moves more and more to an integrated network of providers, it is likely that these same policies will be applied to other health technologies, including home health monitoring systems.

One of the main benefits to integration lies in the ability to share and compare data. Big data is inherently unwieldy and healthcare’s capacity to use this resource effectively has been known to lag behind other industries. It was only recently that hospitals such as the Mayo Clinic teamed up with IBM Watson to better match clinical trial participants with new drugs coming to market, a fairly basic function of the industry.\(^{28}\) Now, new companies, such as local healthcare data warehouse Validic, are aggregating data across system and device platforms. After collecting the data, they distribute it to other ventures eager to identify potential trends and dispense impactful interventions. This benefits

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both the companies participating in this network and the providers and patients they seek to help. By affiliating with organizations like Validic, participants can access their collaborators’ resources and reinforce the value they provide. Synergistic partnerships and additional validation support the legitimacy home health technologies and continue to drive growth.

Highly integrated home health ventures also experience significant financial assistances. These come in the form of specialized investment companies who seek to build a portfolio of symbiotic products and services, and long-term partnerships with hospital systems and primary care provider networks. Echo Health Ventures, a Durham-based investment group, is one example of a concentrated investment firm. With 21 unique companies, three of which were mentioned earlier, they are able to share resources and spread risk. Like Validic, Echo Health Ventures’ connections provide each member opportunities to join forces and tackle home health issues together instead of independently. Unlike Validic, their purchasing power gives them strong in-roads into partnerships with private payers and healthcare systems. If high net worth individuals are willing to invest substantial funds into a new product coming to market, chances are others will take notice.

**Personalization**

Personalizing home health systems is a key tactic to improving functionality and user engagement. Patients’ health status and environmental factors vary drastically across individuals; using a single design that meet all needs simultaneously is neither feasible nor effective. Consequently, new products and services usually mold their strategy to have what they think will be the best result. This may be offering a variety of price points so users can select only features that address their most pressing needs, or developing complex algorithms that match specific lifestyle choices with independent care recommendations. It becomes the mission of the venture to define how they intend to accomplish this individualized approach and at what cost.
Not only do environmental characteristics vary drastically from group to group, as people age, the diversity in cognitive, sensory and motor skills also increases. Cognition impairment, specifically, can radically change the effectiveness of a solution for a particular user and their support group. For example, after a stroke, a care recipient’s loss of ability to process speech, visual information, and complex problems may severely restrict the range of media in which the user can interact with. Personalization from this perspective should be extremely flexible in nature as to adjust to both a sudden change in baseline cognitive capacity and the following slow recovery process. User interface aspects such as font size, voice speed and the number of connected sensors are just a few ways home health monitoring systems can remain practical despite changing parameters.

On the other hand, customized home health systems can facilitate user acceptance and commitment. By incorporating familiar sounds and images into user interfaces, such as an informal caregiver’s voice or face, care recipients may be more likely to be receptive of suggestions and information. Humanizing technology interactions is an excellent way to remove some of the resistance towards its use; it also adds emotional and social elements which enrich the overall user experience.

Medication adherence also benefits from increased personalization. Rarely are two patients’ medication lists the same, let alone their lifestyle and daily activities. Questionnaires and wearable data can help tailor pill regimens to fit the patient’s schedule instead of the patient changing to accommodate the medication. Empowering the patient to make educated decisions on when and how to take their meds increases the likelihood of sticking to the plan significantly.

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Technologies currently on the market typically understand the nuanced nature of healthcare and how the application of home health monitoring systems is very situation specific. However, few have executed on this as effectively as successful as Twine Health. Software and customized care teams are coordinated based on consumer need, financial capacity, and business relationship. This affords both front-end users and large healthcare systems to choose the features and specifications most suited for their circumstance, and then have their data integrated accordingly. Though Twine Health’s approach to personalization is more at the macro-level, they clearly grasp the concept that designing a comprehensive health monitoring system is more than strapping a wearable device on everyone’s wrist.

Communication

Throughout all of the interviews conducted of care recipients, a consistent subject was brought up time and time again: older adults desire to be engaged socially with their surrounding community. In a way, social interaction descends on Maslow’s Hierarchy of Needs as a basic element for survival; feeling a sense of belonging gives both meaning and value to life. These relationships do not have to be with just family alone. Patient’s noted strong bonds with professional caregivers such as nursing aides and medication support services. One particular participant fondly referred to them as “friends who would visit throughout the week”.

Regrettably, the desire to communicate and interact frequently becomes a burden on informal caregivers. This is particularly true for older adults living at home who may have lost a partner or spouse. Family members often become the only social outlet for these individuals and although they try to help their aging loved ones meet new people, finding adequate avenues to connect, providing logistical support through transportation, and mitigating the fears of “strangers”, makes getting their care recipient involved socially a huge challenge. As summarized by one interview respondent,
The patient can never be left alone, outside caregivers are often unreliable, the patient doesn’t want the spouse caregiver to leave him with a stranger, and the caregiving wife is stressed to the hilt.

Most current home health solutions address the communication problem indirectly. For example, a FitBit® can stimulate fun, competitive interactions between family and friends. HomeInstead (an in-home healthcare service) fosters communication by putting an actual person in the care recipient’s home. While these solutions have the ancillary effect of building relationships, their core value exists elsewhere (healthy habit tracking and medical-grade care provision respectively).

Other home health services are starting to emerge that take a more direct approach to improving social engagement. Specifically, LifePod, a digital assistant and virtual caregiver, interacts with care recipients throughout the course of the day using reminders, routine check-ins and randomized events. As a software that operates on top of Amazon’s Alexa Voice service, LifePod has the ability to operate autonomously and inform caregivers of potentially emergent situations should a care recipient not respond promptly. CareLinx and Hometeam are two new hired caregiver models that underscore the relationships and trust. They also integrate their services with mobile software so informal caregivers have the ability to track progress and stay informed.

It is important to keep in mind that communication is not limited to social engagement alone. Many problems associated with the delivery of and adherence to care stems from care recipients (and caregivers) not understanding provider recommendations or what results to expect. Several new digital tools are aimed at tackling these shortcomings, such as UpFront (pre-visit virtual consultations), Wildflower (payer benefit and patient behavior integration), and TrueLink (financial management for seniors). Medisafe is an excellent example of a product which manages medications both from patient and provider perspectives through coordinated pill intake scheduling and adherence monitoring. When patients are able to clearly communicate concerns regarding their medications to providers and caregivers, the likelihood of them sticking to the recommended plan increases substantially.15,16,17
Fostering meaningful communication appears to be a common thread in each technology studied and is the glue that holds the pieces together. Whether it’s helping the care recipient socialize, lightening the burden for caregivers, or increasing the understanding of the healthcare process, communication has an important role to play across all three groups of stakeholders. As new digital health monitoring ventures continue to enter the market, all should consider how their solution will improve communication and emphasize these benefits to the consumers it hopes to target.

Integration, personalization and communication are the three cornerstones to designing a successful home health monitoring system. Each brings their own unique advantages to digital home health monitoring and they are intimately tied to one another. In the next section, additional hurdles facing this industry will be discussed, along with some suggestions on how to overcome them.

Other Obstacles and Ways through the Maze

Outside of the ones identified earlier, there are three other important obstacles facing the home health monitoring industry: standardizing scoring measures, identifying funding sources, and protecting private health data. To some degree, these issues are mitigated by findings noted above. For example, integrating resources forces the homogenization of data, targeting caregivers emboldens consumer demand, and placing systems in the home enlists the end-user’s support of network security. However, focusing on these acute strategies alone will result marginal amounts of success. Waiting for integration to set standards would produce sizeable operational challenges and take much too long; relying on informal caregivers to serve as the main source of revenue is infeasible due to limited spending power; and finally, older adults are disproportionately falling victim to online threats.31 If home health

monitoring ventures hope to set the course for the future of telemedicine; they need to consider how this can be accomplished both in the short and long-term.

**Standardization**

In many cases of clinical measurement, subjectivity is a significant source for data incongruence. This is explicitly true when calculating Adjusted Daily Living scores (ADLs) and assessing cognition impairment (particularly at lower levels), two very important evaluations for older adults.\(^{32,33,34}\) While various studies have looked for ways to normalize and improve ADL and cognition dimensions through shortened tests and added value descriptors, the nature of the tests themselves are inherently dependent on the administrator.\(^{34}\)

Therefore, digital home health monitoring ventures must look to mobilizing their users and encouraging active collaborations with national associations and boards. Both communicative and integrative features of systems can assist this joining of hands, creating another source of value for home health monitoring and telemedicine. Using these technologies to drive the standards of care would cement their place in the healthcare environment.

**Funding**

Receiving payment for digital home health monitoring is a major challenge. Large buyers of health services (ie. insurance companies) have resisted hopping on board for a variety of reasons. Limited validity of device data, low provider interest, fragmented design schemas, and unproven patient value all contribute to an unfertile financial atmosphere. Medicare currently only reimburses for virtual

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provider visits and industry experts estimate it will be another three years before private payers buy-in and other services are covered.

That said, private investment groups and energized consumers remain as potential sources of income while the kinks in the system work themselves out. Engaging pharmacists and payer-backed PCP networks, whose role and distribution model are undergoing rapid changes, are a potential way to spur interest and accelerate development. Studies have also shown that offering small financial incentives to patients using home monitoring devices can further advance the validation process. Before new and existing ventures can attract large investors and purchasers, they will need to demonstrate product legitimacy through leveraging accessible resources and industry champions.

Security

Lastly, consumer healthcare IT and its vulnerability to malicious attacks is the one of the largest sources for uncertainty with the home health monitoring industry. As integration is one of the key components of these systems, a single weakness in the network could place the entire infrastructure at risk. What’s worse is many older adults are unequipped with the necessary knowledge to combat security threats. To add to the complexity, legal barriers are put in place to define the limits of which certain categories of devices or systems are allowed to share. This may be done to protect the interests of the patient, but has the ancillary effect of curbing innovation and collaboration.

Several solutions have been introduced to fight this battle, with limited amounts of success. Private companies such as Apple have developed highly protected open-source software frameworks at the cost of government entities classifying the Apple Watch as a “medical device”. Other studies recommend the use of “broker” servers to store and transmit data, adding an extra layer of security to

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the home network. With the growth of cloud based storage, these types of solutions may be even more feasible than before. The IT industry as a whole is working diligently to stay one step ahead of hackers and protect users, but the odds are stacked against them. To stay afloat, the digital home health monitoring industry must find a way to marginalize security threats and concurrently grow its network.

Conclusion

Three unique stakeholders, design features, and implementation barriers were recognized as having the greatest effect on the development and success of digital home health monitoring systems. By focusing on high level needs of allied stakeholder groups (patients, caregivers, providers); incorporating design features (personalization, communication, integration) that address these needs in concert; and managing current limitations (standardization, funding, security) in the marketplace, home health monitoring becomes a valuable tool in addressing healthcare’s most basic mission: empowering individuals to make informed choices about health while improving the wellbeing of the population as a whole. The graphic below seeks to explain this concept in a visual manner, with narrow arrows representing the flow of determination (dashed = restricted flow) and thicker arrows representing the zones of interrelationship (thicker = more interrelated).

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Prototypes under Development

During the course of this project, two start-up ventures were piloted: Remote Care Connector, a smart home app that uses caregiver customized audio prompts to track a care recipient’s wellbeing; and MedEZE, a medication scheduling app that uses lifestyle questionnaires and wearable data to align pill regimens with daily activities and diet. Both ventures incorporated the findings discussed in this paper and MedEZE was selected as a finalist for the 2017 UNC/AARP Digital Health Innovation Sprint. As these ventures continue to grow, this project will be revisited to include new results.

Final Thoughts and Future Work

Some of the discoveries identified in this project seemed obvious and supported underlying assumptions (ie. the importance of integration); others were less so (ie. patients’ apathy towards loss of privacy). Moreover, the specific aims laid out at the beginning of the report focused more on discrete aspects of specific devices, whereas the final results proved to be broad understandings of the larger home health industry. In all, this pivot yielded more fruitful results than originally anticipated. Additional
research in this field should isolate more examples on the implementation of these discernments to bolster existing and new hypotheses. It is likely that in the coming decade, many of the barriers noted within this report will be removed and distinct recommendations executed upon, making reexamining the core framework of home health monitoring all the more pertinent.
Additional Resources


