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# Integration of Recommendation Systems Into Connected Health for Effective Management of Chronic Diseases

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**ABSTRACT** An important trend in meeting the needs of modern caregiving is providing a well-rounded care delivery. In doing this, access to data of care receiver is important. This, however, has been shown to be possible with connected health with the aid of modern technology. In this paper, we are presenting a design that will expand on the opportunities for better data accessibility and use, by integrating the recommendation system into connected health. In order to ensure a design that meets the needs of care receivers, we conducted two independent surveys with a view to gathering requirements for the design. The result has shown the relevance of timeliness in caregiving along with what the care receivers are interested in such as what their data say about their conditions, the immediate and future expectation of their conditions, and collaborative efforts in managing their conditions. The requirements gathered were used in the design and implementation of the mobile app called Recommendations Sharing Community for Aged and Chronically Ill People (ReSCAP). The benefits of this solution have been real-time recommendations' availability, cost saving, adequate care, and access to health data and information for better care decision-making.

**INDEX TERMS** Recommender systems, connected health real-time recommendations, ReTReSCAP, ReSCAP, healthcare.

## I. INTRODUCTION

Connected health is fast becoming an essential approach for providing a well-rounded opportunity for meeting the needs of modern care giving. Modern care giving goes beyond traditional unidirectional, location-dependent care delivery system. It is important that all stakeholders come to term with healthcare accessibility and data sharing capability in delivering adequate care. Evidence on ground has obviously shown that stakeholders have come to see the benefits of this connectivity. However, there have been serious debates on how to properly connect different health components that will aid various stakeholders in making useful decisions that will impact health of the people. With various modern technologies becoming commonplace and affordable, achieving this may not necessarily have to wait for too long. Researchers working in this research community are already taking advantage of this opportunity. In the recent past, a lot of efforts have been made by researchers working in the domain of healthcare to give Connected Health a face and structure [30]. Although there has not been any specific definition agreed upon by the researchers to precisely define Connected Health, however, various components of healthcare delivery mostly driven by technologies have been brought under the umbrella of Connected Health. Connected Health can also be seen from the perspective of its objectives namely data sharing and improved accessibility to healthcare services regardless of place of domicile of care receiver [11]. Although with no single definition agreed upon notwithstanding, it is easy to perceive what researchers understand to mean Connected Health, from the objectives of this approach. In view of this and bringing together various descriptions by experienced researchers, Connected Health can be referred to as a conceptual model for health management where devices, services or interventions are designed around the patient's needs, and all health-related data are shared with improving accessibility to healthcare services by people everywhere –urban, rural and remote communities-in a sustainable way [11], [12], [20], [26], [35]. Practice such as telemedicine which brings affordable and effective care to people living in sparse

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and remote places [11], is an essential component of Connected Health because it enhances accessibility to care services. It can be seen however, that achieving full potential of connected health though requires strong technological infrastructure and fast internet connectivity which only are available in developed countries such as the USA, Finland, the UK and Germany. Developing nations also have the prospect of benefiting immensely from Connected Health by improving on their existing infrastructure, good synergy with the business world, and by taking advantage of other evolving technologies. Healthcare delivery is faced with a lot of challenges ranging from data access, disjointed health information databases, and the attitude of medical personnel and patients to health data sharing and use. Addressing these challenges is germane to the provision of effective care and its sustainability. In view of this, the sustainability of future healthcare delivery is an important challenge that Connected Health can be used to address [35].

Ensuring accessibility to healthcare services as well as improved data sharing and use involves connecting not only the sources that will provide true reflections of individual's health and lifestyle but also stakeholders who can make effective use of such connected data for making helpful decisions that will impact the health of care receivers. Connecting all data sources such as the Electronic Health Record (HER), data from sensors and devices, data on fitness and lifestyle, and data on diets and allergies, and interacting stakeholders is inextricably linked to provision of a well-rounded care giving [20]. With a good framework and formidable information exchange protocols, seamless connection of these various components is practical. This will enhance effectiveness of care delivery and allow fast interventions. Despite worrying issues relating to security and confidentiality breaches, framework limitation, reusability, trust, Privacy, and interconnectivity problems [6], [34], [42], many of which are being addressed by the research community [30], the field of Connected Health stills stands as a promising approach for meeting the challenges of modern care giving.

Recommendation systems have come to play an important role in care intervention and helping care seekers get information that may help them make impactful decisions regarding their health. Recommendation systems use the data by the user or past evaluation as input to make recommendations to the user [33]. Information on the preferences of users can be collected from different sources to make predictions and recommendations of items [10]. This can lead to robust recommendations. As a result, integrating recommendation systems into the Connected Health with multiple sources of health data has the potential to generate robust health recommendations for better care decisions. The relevance of recommendation systems in modern healthcare delivery cannot be underestimated. Because of recommender system's ability to infer the needs of each person and then to satisfy those needs [40], its integration into Connected Health has potential to deliver a more personalized care service, delivering right information to the right people at the right time [14].

In our earlier works, we proposed the integration of recommendation system into home care [2], [3] to provide personalized health recommendations based on data generated from home in real-time. Our work has focused on connectivity of health components and access to data real-time to make real-time recommendations. In this paper, we are expanding on the potential roles of recommendation systems in Connected Health. More important is the capacity of recommendation systems to play a supportive role in enhancing accessibility to personalized care through effective use of shared data for decision making. Using requirements gathered, we have been able to design an integrated approach for connecting health components that has the potential to deliver effective care. Part of the design feature has been implemented through a mobile app called ReSCAP which is community part of the entire design of a platform for caring for the elderly and people living with chronic illnesses.

The rest of the paper is divided as follows. Following the introduction in section I, the review of literature is presented in section II. The research design is explained in section III. Section IV presents the result and discussions while the benefits of the design are discussed in section V. The conclusion is presented in section VI.

## II. LITERATURE REVIEW

In the following section, we are going to discuss some trending subjects in literature and how they relate to our work.

### A. CONNECTED HEALTH

Connected Health (CH) has come to be a term used when talking about bringing together of all components of healthcare delivery services with a view to expanding accessibility to care services and data sharing for delivering effective care. This involves all different data sources that can provide information about the state of health and wellbeing of an individual and connecting them together using modern technologies. The population of older citizens is expected to rise in the coming decades, and this is to come with high cost of providing health care services along with dwindling care personnel [46]. Connected health can prove to be an alternative way to deliver sustainable healthcare in the most efficient way. It is generally agreed that the future challenge of healthcare sustainability depends on Connected Health [35]. With Connected Health, various healthcare components are brought together for ease of data sharing and effective care. In defining Connected Health, community members working in the field are yet to agree on a precise definition. However, Connected Health includes healthcare approaches that cover digital health, eHealth, mHealth, telecare, telehealth and telemedicine [15]. In addition, [12] defines Connected Health as a conceptual model for health management where devices, services or interventions are designed around the patient's needs, and health related data are shared, in such a way that the patient can receive care in the most proactive and efficient manner possible. In a broader sense therefore, Connected Health is the collective term for telecare, telehealth,

telemedicine, mhealth, digital health, and health services. It involves the convergence of health technology, digital, media, and mobile telecommunications [16]. It is important to note that Connected Health increases data and information accessibility by patients, care givers and health care providers to improve care quality and care outcome. While it may generally be assumed that, due to high infrastructural and fast Internet service requirements, only developed countries stand to benefit, practices such as telemedicine which brings affordable and effective care to people living in sparse and remote places [11], can benefit developing nations where accessibility to health facilities remains a problem. In providing this essential service, stakeholders can collaborate to seek alternative solutions that are cheap and durable. From another perspective, we feel that a working definition can be derived from the general objectives of connected health. Such objectives as improving accessibility to healthcare services by people in rural and remote communities, reducing unnecessary hospital visits and travel in a sustainable way [11], thereby reducing the overall cost of delivering effective care. Best result can be achieved if Connected Health is proactive and built with patient in the center to facilitate efficient management of wellness and health throughout their lifespan [12] Another interesting advantage of Connected health is seen in its ability to promote right information to the right person and at the right time [14].

The future of connected health will be brighter if the connectivity can include an individual's behavior, nutrition and activities [20]. This kind of well-rounded care delivery becomes much more effective with the integration of recommendation system illustrated with the framework presented in this paper. One of the areas of concern that Connected Health will have impact, besides caring for the aged (such as in [42]), is in the management of chronic diseases [6]. As a result, many researchers working on Connected Health are already testing the relevance and applicability of connected health in the management of chronic diseases such as cardiovascular disease [7] and dementia [18]. In confirming the practical applicability of Connected Health [41] reported a project which produced WIISEL (Wireless Insole for Independent and Safe Elderly Living) system, designed to monitor fall risk and to detect falls in older people [42]. Several other projects have been funded in this domain of research [13]. More and more researchers are concentrating on using the provisions made possible by Connected Health to provide care for older population and manage people with chronic diseases [14]. These examples highlight the potential of Connected Health for meeting the needs of current and future health needs of care receivers.

Like in all healthcare systems, there is the worrying fear of breaches of security and confidentiality [42]. Others are worried about the limitation imposed by current health technology framework in terms of flexibility, engagement and reusability of connected components [34]. However, it is soothing to know that there have been efforts to enhance and improve security and privacy of connected health applications [1], [17], [32], [48], [49]. Pooled together, the healthcare ecosystem will have to contend with increasingly large volume of data, which must be put to good use to benefit all stakeholders [35]. This heap of relevance data can be a good source of information for recommender systems for use in rendering personalized services to care receivers.

Many research works have focused on presenting framework that will support the realization of the vision of connected health. These frameworks have different objectives such as helping in the development of Connected Health applications with reusable and customizable components [34] while some are more concerned about care pathways and information flow and thus working to model these [36]. Providing interventions that will be effective and meet the needs of modern care giving will also require Connected Health that meets users' and stakeholders' requirements. Therefore, an important step in meeting these requirements is to identify them. As a result, a framework that can assist in doing this is a major focus of some researchers [30]. Evidently, a lot of people are working in this community and many solutions and frameworks are beginning to emerge. This flurry of excitement for the potentiality of Connected Health to deliver effective and well-rounded care for the elderly and chronically ill people comes with its own challenges besides the towering benefits. One of such challenges is effectiveness of solutions provided and developing a framework for evaluation of solutions in Connected Health has received attention by experienced researchers [36] experiencing effective impact of connected health technologies requires adequate tool, models and framework. Members of Research community generally understand this and are working toward it and the design of software to support connected health delivery [30].

To put connected health in a proper perspective and enhance its acceptability and effectiveness, all efforts at connectivity must be inclusive. This implies bringing together all stakeholders such as the patients and care providers as the primary leaf of the stakeholder's tree. However, realizing success will involve strong investment in the solutions provided. As a result, there must be strong alliance among society, businesses people, professionals, and individuals [5]. Modern technology and phenomena such as the Internet of Things must be exploited for achieving connectivity and access at various access points [26]. Collaborative and multidisciplinary research along with inclusive policy of absorbing others who render health services such as community pharmacist are good options to consider [4], [9]. It is noteworthy that people are already perceiving the benefits of Connected Health in the areas of better quality of healthcare, location-independent access to healthcare services, and better quality of life [22].

### B. RECOMMENDATION SYSTEMS IN HEALTHCARE

Recommendation systems have played significant roles in healthcare and wellbeing. Recent technological advances in communication technology are being used for personalized

health recommendation systems [47]. Some studies have suggested areas where future work on health recommendation systems will focus, such as integration with electronic health records [24]. This is in line with our earlier proposal, especially in connection with our current Real-Time Recommendations Sharing Community for Aged and Chronically Ill People in Connected Health (ReTReSCAP-CH) project. There are also reported efforts on the use of recommendation systems for wellness therapy [31]. Many of the recommender systems for healthcare are deployed towards addressing specific challenges facing healthcare professionals such as reduction of errors in daily clinical consultation [50], Nutrition recommendation for the care of the elderly [19], helping patients living with chronic diseases to monitor and control their cases [25], providing patient eccentric services [25], providing personalized treatment recommendations [27], while others are disease-specific [45], helping providers acquire required knowledge in their profession real-time [39], and personalized food recommendations [43] among others. These efforts already made in the application of recommendation system to the field of healthcare in general and in helping to deliver care for the older one and managing chronic illnesses, indicate their potentiality in Connected Health.

## III. RESEARCH DESIGN

The research was conducted in different phases, with the outcome of one flowing into the other or leading to the other. The phases include identifying stakeholders, analyzing and gathering requirements, and designing. Various methods for identifying stakeholders, elicitation and analyzing of requirements have been proposed and used over the years [8], [21], [23], [28], [29], [38], [44] and these methods and approaches have their strengths and weaknesses. These range from informal to formal methods. Researchers have, at one time or the other, provided justification for use of each of these approaches. While many of these approaches have yielded better results when used in complex situations, many of these methods are not simple to use. Our focus in this work is neither to assess the effectiveness of any of these approaches nor compare one to the other. Based on the nature of our project, the ecosystem, and the intention to use a simple approach not necessarily with any intent to devise something new, we have devised a simplified approached called Training Logic Concept.

The simplified Training Logic Concept was conceived based on the universal approach to training analogous to simple school system. In the universal training system approach, trainees are the primary stakeholders, first to be identified, along with the goal of the training, is identified. It is logical to conclude that tutors are only sought following identification of trainees. Therefore, Training Logic Concept (TLC) was borne from this logical conclusion. The theory behind this choice and other arguments along with application to other scenarios are examined in another paper. However, the Training Logic Concept has four major components or legs when depicted like a tree. They are Trainee, Goal, Tutor, and Mean (Trainee-Goal-Tutor and Mean (TGT-M)). This concept is a requirements identification and analysis tool initially conceived as Tutor, trainee, and objects (TTO). However, after applying the initial concept to some practical scenarios it became necessary to provide some refinements to make it conform to the rule of logic and reality, especially in healthcare as a result of feedbacks on its use. While we have essentially designed this tool for use in requirements identification and analysis in healthcare, we are sure it can be applied in practically several other domains.

This concept essentially acts as a guide for requirements identification and analysis. It starts with the trainee as an 'object' who needs to be trained. Then it proceeds to the goals of the training. The next step is to identify the tutor who will provide the training. In applying this concept to a technology-driven scenario, the tutor can be human or any other device that can be used to achieve this aim. In a typical school system, which in our analysis and from our observation also holds in the healthcare system, the order Trainee-Goal-Tutor-Mean is discernible. Finally, the means of assisting all interacting objects to meet the goal is identified. In a typical school system, there are people who want to learn. The goal is to get them educated. How can this be realized? Teachers are recruited. There are other materials and non-materials needed to assist teachers and students achieve the set goal, namely school building, white board, chairs and tables among others. This is similar to what obtains in healthcare system where primarily there are patients who need care. The goal is to help them get better or successfully cope with their conditions. Physicians, Nurses, Medical and laboratory scientists along with other material and non-material equipment are needed to restore patient to good health and manage their conditions quite reasonably.

### A. STEP 1: IDENTIFTING PRIMARY STAKEHOLDERS AND REQUIREMENTS

In our research, the trainees are identified as people with chronic diseases and the elderly. The goal is to provide effective care that will promote healthy living in people with chronic diseases and effective management of their conditions. The tutor needed in this instance is the medical personnel such as the Physicians, Nurses and others who work with them. The means of achieving our goal of effective care is Connected Health. The thought of one object clearly leads to identification of another during the analysis. For instance, while analyzing the means of achieving the objective, the primary means is through Connected Health, but further analysis will lead to other elements of connected health such as data sources, the Internet, IoTs Infrastructure among others.

Trainee = {chronically ill people, elderly}
Goal = {Effective care, better condition management}
Tutor = {Physicians}
Means = {Connected Health)

### B. STEP 2: GATHERING SPECIFIC REQUIREMENTS

In gathering the requirements for the overall design of ReTReSCAP-CH, we adopted a requirements gathering-style survey which was done in two phases. The first phase involved a mix of all stakeholders such as patients, Physicians, researchers, software developers, caregivers and other health workers. The second phase was specifically narrowed down to the primary stakeholders whose needs are primary in these case- patients while those of others revolve around them [11]. As a result we used people living cancer and HIV/AIDS. We wanted to know their relevant health needs and the kind of support they would need with the use of technology. Both diseases require effective management to halt lethal progression.

In determining general design requirements, we conducted an online survey, and various stakeholders were invited to respond. The criterion for invitation was basically their experience and contributions to the research community. Reminders were sent occasionally. Those invited were researchers and professionals who include Physicians, nurses and others working in healthcare domain. The objective was to understand their perceived technology needs of people living with chronic disease and the criteria for evaluating solutions developed to meet such needs. A few Patients were also invited to respond. of the 43 individuals who responded, 36 considered timeliness of health recommendations important, 41 persons indicated the need to have immediate and future expectations of the disease while 36 respondents felt that real-time recommendations are important.

The second survey was to gather requirements that address the specific health and technology needs of people living with chronic diseases. In doing this the survey primary targeted patients themselves who are living with two of the identified chronic diseases. The survey-style requirements gathering involved some 20 individuals living with a chronic disease namely cancer and HIV/AIDS, randomly selected. This was done to better understand their needs and what kind of technological support they desired. Due to confidentiality issue, we agreed not to take any personal information from them. The interactions were conducted in English. An expanded survey that will include more chronic diseases across different nationalities is ongoing.

## IV. RESULTS AND DISCUSSION

In this section, the results of the two survey-style requirements gathering activities are presented and discussed. This includes the general design requirements gathering and the needs specific requirements gathering. Besides, the requirements were used to design the possible integration of recommender system with Connected Health and the mobile App called Recommendations Sharing Community for the Aged and People living with Chronic Illnesses (ReSCAP), which is a component of ReTReSCAP-CH.

**TABLE 1. Summary of survey.**

| | Number | List |
|---|---|---|
| Respondents | 43 | |
| Countries | 8 | |
| Continents | 4 | Africa, North America, Europe, Asia |
| Profession | 4 | Recommendation systems researchers and developers, Physicians, Patients, Nurses, Members of International Organizations |

Table 1: Summary of information on respondents to Survey on General Requirements.

### A. GENERAL DESIGN REQUIREMENTS

The survey-style requirements gathering was conducted by putting the survey online to allow a good number of invited respondents to have unreserved access to it. The individuals invited were notified by email and repeated reminders were sent. After three months, 43individuals had responded to the survey. These researchers, who have made substantial contributions in the field, come from different backgrounds such as recommender systems development, research, hospitals, and membership of international organization for chronic illnesses, Physicians, nurses, and patients. These come from four continents of Africa, Asia, North America and Europe. The total countries represented are eight. The summary of the survey is presented in Table 1.

A key issue at the heart of the requirements exercise is to ascertain the relevance of timeliness and Real-time recommendations to the design of a well-rounded solution that will address the needs of modern and future caregiving from professionals' perspective based on their research and work experience. The choice of the two criteria arises from (i) the result of pre-survey interactions with various health stakeholders, (ii) the result of the analysis of literature review on works of experienced researchers in the field of recommendation systems, and (iii) the observable trends and future expectations in modern care giving. It was clear from the response that timeliness of health recommendations is very relevant in judging the overall effectiveness of health and wellness solutions. Table 1 shows the response of the stakeholders to the relevance of timeliness of health recommendations. With the response indicated in the table, it was obvious to us that any design that will provide a well-rounded health and wellness solution should consider timeliness of health recommendations as a relevant feature.

Figure 1 pictorially illustrates the relevance of timeliness to a well-rounded healthcare system solution. The reasons for the choice of this criterion have been indicated in subsection A of this section. As indicated in Table 2, Forty-One of the Forty-three stakeholders chose to rate this metric against the eight other criteria. Only one respondent considered this

**TABLE 2.** Relevance of timeliness.

| | Rank | Response | Percentage |
|---|---|---|---|
| Least Important | 1 | 1 | 2.4 |
| Less Important | 2 | 5 | 12.2 |
| Important | 3 | 8 | 19.5 |
| More Important | 4 | 13 | 31.7 |
| Most Important | 5 | 14 | 34.1 |
| **Total** | | **41** | **100.0** |

Table 2: Response of stakeholders on relevance of timeliness of health Recommendations

**TABLE 3.** Relevance of real-time health recommendations.

| | Rank | Response | Percentage |
|---|---|---|---|
| Least Important | 1 | 3 | 7.0 |
| Less Important | 2 | 5 | 11.6 |
| Important | 3 | 8 | 18.6 |
| More Important | 4 | 12 | 27.9 |
| Most Important | 5 | 15 | 34.9 |
| **Total** | | **43** | **100.0** |

Table 3: Response of stakeholders on the relevance of real-time health recommendations

metric least important. This represents just 2.3%. However, 13 respondents representing 30.2% considered the metric more important than the others while 14, representing 32.6% chose the metric as the most important over the others. This result, no doubt shows the relevance of timeliness to the stakeholders in judging the effectiveness of a healthcare solutions and in justifying the reason for including it as a design feature.

Another key criterion for consideration is the design that will make allowance for providing real-time health recommendations. As indicated in Table 2, participated stakeholders feel this criterion is important to the overall relevance of any solutions that will be designed. Among the eleven criteria rated by the stakeholders, the need to for real-time health recommendations is obviously emphasized.

Figure 2 as well as Table 3 indicates the response of forty-three (43) stakeholders on the relevance of real-time health recommendations to a well-rounded healthcare solution. Three (3) of the respondents representing 7% shows that getting health recommendations real-time is least important while 12 and 15 respondents representing 27.9 % and 34.9% respectively agreed that the criterion is more and most important. The combined agreement of these groups is indicative of the relevance of real-time health recommendations and is therefore important to be included as a design feature.

### B. THE NEEDS SPECIFIC REQUIREMENTS

The need-specific requirements gathering was conducted among randomly picked individuals living with cancer and HIV/AIDS. They first indicated what kind of needs they have

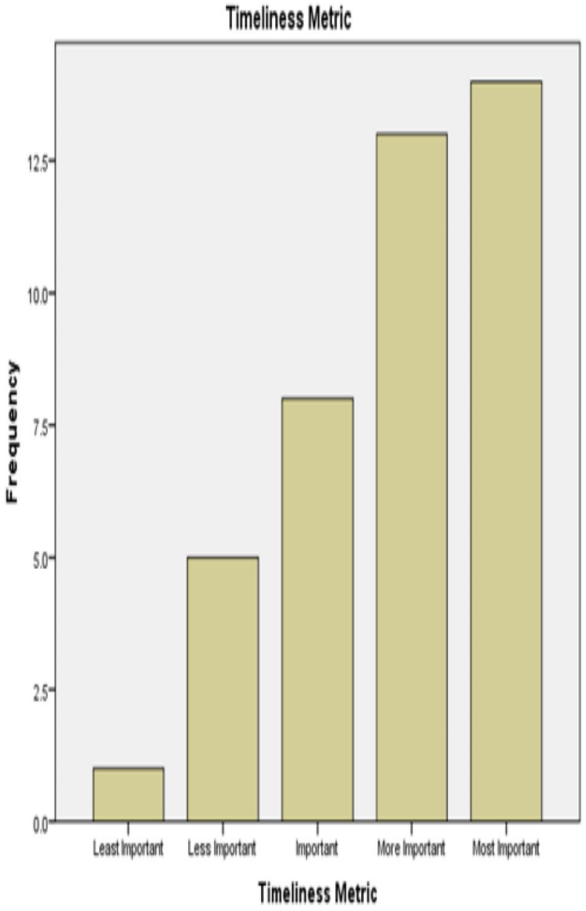


**FIGURE 1.** Timeliness as a relevant metric in health recommendations.

based on their conditions. Higher percentage of them chose Physician Guidance as their priority, followed by Education and awareness about the condition while Socializing with others has the lowest pick. Next was to ascertain the kind of intervention they expect from different technologies. They agree that they will need technology support in contacts with others living with the same disease to share essential information. The preferred contacts are other patients, physicians, in a community-like association. On the kind of information that will prove useful, they would like to be kept up-to-date with information about current treatment methods, drugs, dietary advice, fitness and lifestyle. The implication of this is that to get a well-rounded design that will inform the expected solution, all data sources including these desirable parameters should form part of the design. The respondents would also like to know the immediate and future expectations of the chronic diseases to help them prepare for immediate challenges and possible avert future problems. Therefore, any technology-driven solution that will support these features is readily acceptable to them.

In our classification based on priority placed on the expected technological interventions, getting notified of potential danger, belonging to a community to share information, update on treatment methods, and understanding

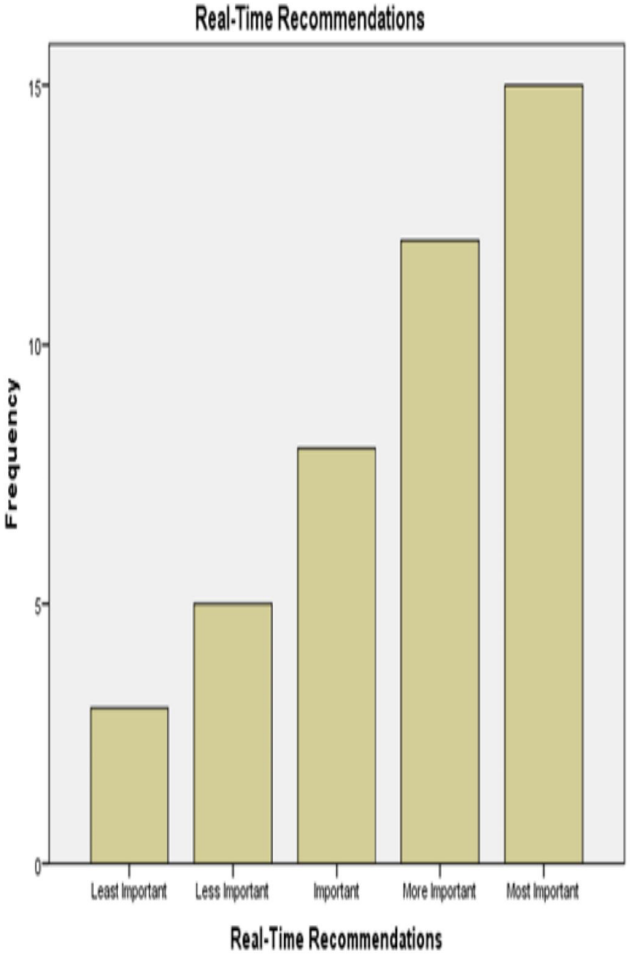


**FIGURE 2.** Stakeholders' perception of real-time recommendation as a criterion showing the frequency and the rank for the degree of relevance as perceived by stakeholders.

immediate and future expectation about condition have HIGH priority while provision of rehabilitation services and remote mentoring have LOW priority among the respondents. Majority of the responded agreed that they are more comfortable with using smartphone while they overwhelmingly chose to have health information delivered to them in text and video formats. However, significant number would like to receive health information via audio and game.

### C. INTERACTIONS AMONG OBJECTS

To ensure well organized and defined interactions among the objects in the home unit, it is important to properly define the modalities for interactions among the connecting objects in the home. For any interaction to be approved in the home, the basis for interaction must first be established and verified by the moderating AI system. This basis is established if the objects intending to interact with other objects carry identity that indicates that they have been properly initiated and belong to the same class of recommendations sharing community. This is an important step in the entire process and thus determines whether an interaction will be allowed or not.

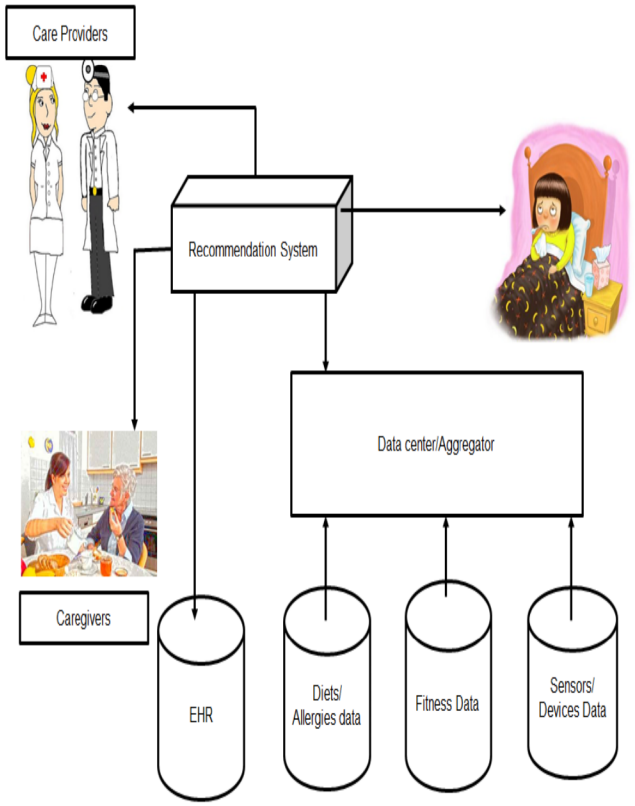


**FIGURE 3.** The architecture for integration of recommendation system in connected health.

### D. THE DESIGN

Our analysis of the data from our respondents clearly indicates that people with chronic health conditions are interested in the following

1. what their data say about their condition
2. The immediate and future expectations of their conditions
3. Collaborative efforts in managing their conditions.

In satisfying the above, there is the need for a well-rounded design of connected Health. Further analysis of each of the above key extracts informed the architecture depicted in Figure 3. Future design of this approach might include personal needs determination for execution by the caregiver or house help in a more radical way, by a robotic shopping assistant, using the daily needs history, dietary calendar or meal timetable to decide daily or weekly needs. Inclusion of daily Personal Health History analysis, showing current state of health and the possible future progression and offering recommendations to avert crisis via a video console, is also a possibility. However, because of hugeness of the project and its heavily infrastructure-dependent nature, a practical business models without which adoption will face problem [12], should be sought. The design of this kind of approach will expand the list of stakeholders to include business-oriented research and development institutes, Healthcare international organizations and government.

The architecture indicated in Figure 3 illustrates the integration of a recommendation system in Connected Health. Our concept of connected health involves access to all relevant data in order to be able to give what can be called ''total and effective intervention'' in caring for a person with chronic illness. The architecture shows different sources of data around a chronically ill person. Such sources are data from sensors and other devices attached to the home, data on diets and allergies, data on fitness and lifestyle which can be from wearables and in some cases from smartphones. All these are aggregated for use by a data aggregator. The role of data aggregator is to pick essential data from different repositories and store them in a format that will make their access and use easier by various stakeholders. The moderating Artificial Intelligence system can also pick data from here for use. However, the recommendation system accesses relevant data through the data aggregator and uses this along with relevant history from the patient's EHR to make recommendations regarding the health of an individual at home for use in decision making. These recommendations can be made available to various stakeholders depending on their roles and responsibilities. These stakeholders are the patient, the care providers, and the care givers. For instance, certain information from the sensor about the patient sugar level may be combined with the patient's history of sugar level to give recommendations on potential immediate and future health implications. These can be made available to patient or care providers.

### E. BUILDING BLOCKS FOR ENHANCING PRIVACY AND CONFIDENTIALITY

Ensuring confidentiality and privacy is an important issue in healthcare generally and especially in Connected Health with interconnectivity of various data sources and stakeholders across different technologies and varying protocols. In the ensuing design of the integration which includes ReSCAP which is the community platform of ReTReSCAP-CH, provisions have been made for enforcing privacy and Confidentiality during transactions within and across communities. This has been done by including mechanism that will ensure enforcement. This mechanism has been built on two confidentiality-enhancing policies namely *traceability* and *accountability* illustrated in figure 4. This mechanism is built on verifications using uniquely generated ID which carries verifiable and identifiable information about the Home or Community, as the case may be, the kind of service rendered by the object, the object's own identity, and the initiation code which is generated following the object's initiation and acceptance into the home or community. The enforceability of this process is part of design issues in the overall design of the solution for integration of recommender systems into Connected Health. The applicability of this is illustrated in the implementation of ReSCAP. The building blocks are based on identity confirmation and verifications (e.g. home – community, community-community) driven by policies of accountability and traceability coordinated by the moderating Artificial Intelligence System.

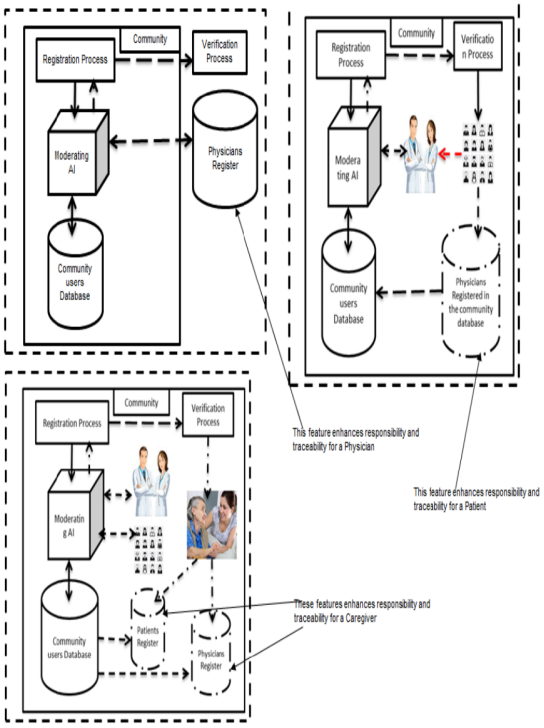


**FIGURE 4.** The internal mechanism to ensure traceability and accountability of care providers such as the Physician and the care giver.

### F. RECOMMENDATIONS SHARING COMMUNITY FOR AGED AND CHRONICALLY ILL PEOPLE

The Recommendations Sharing Community for Aged and Chronically Ill People (ReSCAP) is a mobile app that provides a platform for stakeholders involved in delivering effective care to interact and share recommendations in real-time. It provides a closed-circuit platform for these individuals to be able to share treatment methods, drugs, and nutritional advice used and found to have worked. The platform also provides opportunities for them to interact real-time making it possible for a physician to provide continuous and remote care. It is an extension of the home design illustrated in ReTReSCAP-CH. Figures 5 and 6 illustrate some of the features of the app. When it is fully implemented, it will be possible to integrate the home and the community for seamless interactions. It is important to say however, that this app was developed primarily for people living with chronic illnesses. Notwithstanding, some aged people may find the features of the app useful, provided they are physically able to use it. Evaluation of this app, using a checklist developed earlier, is ongoing.

## V. BENEFITS OF THE DESIGN

### A. REAL-TIME RECOMMENDATION POSSIBLE

With the integration of recommendation systems, it is possible to use data generated real-time to make recommen-

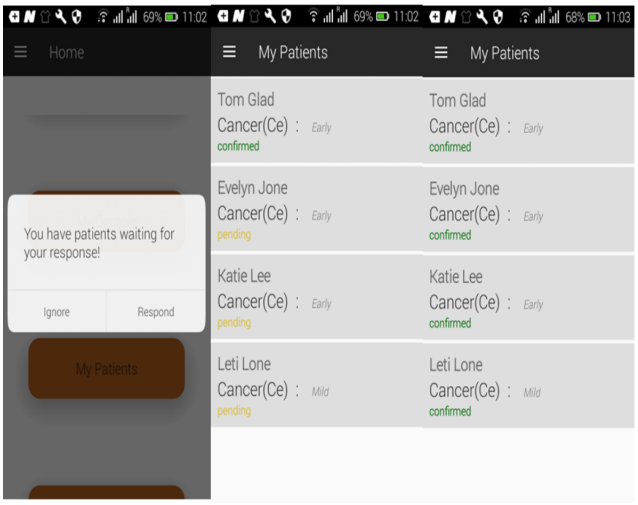


**FIGURE 5.** Patients-physician closed relationship illustrated in ReSCAP.

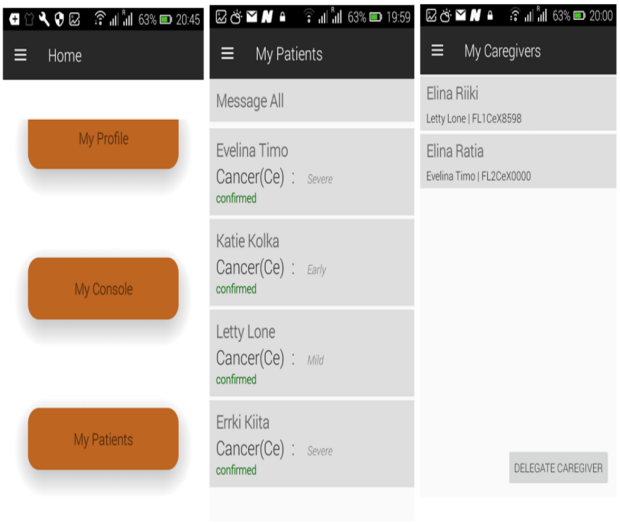


**FIGURE 6.** The illustrated patient-physician-caregiver network in ReSCAP.

dations to the patient, physician and other caregivers on the immediate and future states of health of the individual receiving care. This can help avoid some damages to the health condition of the individuals. It is also possible to make predictive recommendations based on different data sources available in the Connected Health ecosystem. Other types of recommendations possible are corrective and preventive.

### B. COST SAVING

Most researchers have agreed that implementing Connected Health can reduce the cost of hospitalization and the cost incurred from frequents hospital visits. Cost of personnel required to attend to the needs of people living with chronic diseases will also be reduced. As a result of the ability to make predictive recommendations by the integrated recommendations system, preventive intervention is possible, which in the long run reduces the cost of care.

### C. ADEQUATE CARE

Adequate care in a broader sense implies a well-rounded care provision that contributes to both the immediate and future health of care receivers. It also includes care giving that affects all aspects of human health and wellbeing. The aim of Connected Health is to provide this kind of care. However, with the integration of recommendation system, this kind of adequate care is possible.

### D. ACCESS TO DIVERSE DATA SOURCES FOR DECISIONS MAKING

An important feature of care giving is access to diverse data sources by relevant stakeholder to make effective decisions on the health of those receiving care. Besides having access to data, another issue is how much of the required data is available for use? Data availability is essential to making right decisions that will impact the health of care receiver for good.

## VI. CONCLUSION AND FUTURE WORK

The fervor behind Connected Health (CH) is the possibility of providing adequate care through effective accessibility to and use of data, driven by modern technologies. In bringing this to fruition, all different data sources that can provide information about the state of health and wellbeing of an individual must be brought together with regulated access to them for use in effective decision making on the state of health of care receivers. With the integration of a recommendation system into this connectivity, radical changes are made possible in the way health care is delivered to older citizens and people living with chronic diseases. Designing a system from the tip of our imagination may not achieve the desired objectives without taking into cognizance the health needs of individuals for which we are designing, and the interventions expected from modern technologies. As a result, we conducted two independent surveys in a bid to gather requirements for the design of a system that will deliver an effective connected Health. The analysis indicates that people living with chronic conditions would like to know what their data say about their condition, the immediate and future expectation of their conditions and Collaborative efforts in managing their conditions. Majority of the respondents agreed that they are more comfortable with using Smartphone while they overwhelmingly chose to have health information delivered to them in text and video formats.

We have also illustrated with the architecture presented in this paper that Connected Health, when integrated with recommendations system, will in the most efficient way provide sustainable healthcare delivery. Achieving effectiveness in healthcare delivery will require seamless connection of various components of health services, data repositories on patient's health, wellness and lifestyle. This will also require connecting all relevant stakeholders such as the patients, physicians, caregivers and in some cases, business world, and government.

In addition, the requirements gathered from the two surveys have been used in the design of and implementation of the mobile app called Recommendations Sharing Community for Chronically ill People (ReSCAP). This mobile app provides a platform for individuals living with chronic conditions to interact and share recommendations real-time. When fully implemented, this platform can make physicians and other relevant caregivers have access to data generated by the person receiving care for effective decision making for adequate care giving. With the integration of recommendation system, care providers and care receivers can get information and recommendation about their immediate and future state of health real-time.

We have highlighted the benefits of this solution to be the possibility of real-time recommendations availability, cost saving, adequate care, and access to health data and information for better care decision making. In a bid to expand the design and implementation of this solution, we have an ongoing effort to gather further requirements that will help us compare the health needs and required technological interventions for some selected chronic diseases with related symptoms and treatment options with a view to creating a platform for synergic relationship. Although lack of fund and reluctance to volunteer information by some people living with chronic diseases are serious limitations of the project, however, we hope to do full implementation of the integrated architecture of home and community care platform which we have designed.

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