Sustainable, Holistic, Adaptable, Real-Time, and Precise (SHARP) Approach Towards Developing Health and Wellness Systems

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Abstract. As populations age and chronic diseases become more prevalent, new strategies are required to help people live well. Traditional models of episodic health care will not be sufficient to meet changing health care needs and the reorientation of services towards maintaining function as opposed to treating illness. One strategy to meet these challenges is an increased focus on self-care via use of broader social networks and seamless integration of applications with lifestyle activities, particularly for people with chronic diseases including diabetes, cardiovascular disease, and respiratory conditions. There has also been a rapid increase in a range of technologies for connecting different components of the health system and delivering services through smartphones and connected devices. Our proposal is to pursue systems development in healthcare in a way that considers a range of aspects known as SHARP: Sustainable, Holistic, Adaptive, Real-time and Precise. This approach will provide solutions that will be useful and effective for managing the long-term well-being of individuals.

Keywords: Sustainable health systems · Precision health · Disease management · Adaptive health systems · Self-managed healthcare applications

1 Introduction

As populations age and chronic diseases become more prevalent, new strategies are required to help people live well. Traditional models of episodic health care will not be sufficient to meet changing health care needs and the reorientation of services towards maintaining function as opposed to treating illness.

One strategy to meet these challenges is an increased focus on self-care and the use of broader social networks and integration of technologies and seamless applications to support health and wellness activities of individuals, particularly for people with diabetes, cardiovascular disease (ischemic heart disease and heart failure), and respiratory conditions including asthma and Chronic Obstructive Pulmonary Disease (COPD). In New Zealand, the Health Research Council (HRC) has issued a 2016 health and

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wellbeing research investment signal with a specific focus on keeping people healthy and independent throughout life [1]. In the last 18 months, the Ministry of Health in New Zealand has heavily promoted the use of *patient portals* to improve patient engagement with their own care, and has just funded a training program to help primary care support self-management, primarily focused on diabetes care [2]. Another strategy is the refocusing of health systems, particularly the UK NHS, on the experience of the *health consumer*, measuring patient experience both as a mechanism to tune systems to better meet need, and also as a primary outcome [3]. Against the background of these philosophical shifts, there has been a rapid increase in a range of technologies for connecting different components of the health system and delivering services through smartphones and connected devices.

Our proposal is to encourage *systems development in healthcare* in a way that considers a range of aspects we named SHARP: Sustainable, Holistic, Adaptive, Real-time, and Precise. This approach will provide solutions that will be useful and effective for managing long-term wellbeing of individuals.

1.1 Motivation and Gap

The motivation for this work stems from the following challenges in healthcare around the world.

- A*geing populations*, which consume a greater amount of healthcare services and have limited tax-raising ability.
- *Longer life expectancy* of individuals [4], and this involves *long-term disease management*, which changes the paradigm of treatment from episodic to ongoing.
- *Disadvantaged communities.* For instance, in New Zealand the type-two diabetes prevalence is seven percent, with higher rates among Maori (9.8 %), and Pacific peoples (15.4 %) [5].
- *Changing lifestyle patterns* of single parents, smaller families, and unhealthy lifestyle factors particularly smoking, physical inactivity, poor diet quality, and stagnant or worsening rates of obesity [6].
- *Raised patients' expectations* of healthcare to be delivered in a way that leverages digital devices and web technologies. For example, the authors in [7] state that shared medical records including Internet-accessible records are almost universally endorsed across a broad range of ethnic and socioeconomic groups.

The gap occurs because current health programs, initiatives, systems, and applications focus on specific outcomes of medical treatment, awareness, and communication between patient and health services. The treatment from a clinician-patient interaction perspective is often episodic, meaning the treatment plan is adjusted every time the patient is seen by a medical professional. After each episode, patients find it challenging to adhere to recommended self-management programs, particularly the adoption of different lifestyle patterns. During the time the patient lives independently (which is desired) away from health services, the mismanagement of diet, exercise, and medication adherence contributes towards unfavorable health outcomes.

To develop systems and processes that can sustain long-term success and appreciate the holistic nature of healthcare delivery, we propose development of solutions that are standardized and integrated across a full range of stakeholders. The following section presents the SHARP approach to build and evaluate successful eHealth projects.

2 SHARP Approach

The key research question is how do we care for the wellbeing of our ageing, yet-to-age, and individuals with chronic illnesses in a holistic and sustainable manner? This study aims to provoke research and develop projects that implement and evaluate a SHARP approach for management of chronic diseases to support and enhance the well-being of the population.

The SHARP approach is both a concept and a process (Fig. 1). We believe that having a sustainable vision for society and the individuals and communities within it is at the heart of the approach as well as its starting point. To carry out this vision, we need to have a holistic perspective that spans the multiple dimensions of the individual. Furthermore, we need to build within the people, processes, and systems the ability to be adaptive and agile, and to learn, and respond. This can only be accomplished if we have access to real-time information — information that is available to different stakeholders at the right time, right place, and appropriately personalized so they can make quick and effective decisions based on scientific evidence derived from trending historical data. The afore-mentioned real-time data will be captured via devices and sensors and rigorous analysis. It is this type of personalized, preventative, predictive, patient-centered, and precise information that will result in solutions to support health goals of individuals, communities, and society. The following sections articulate the SHARP concepts and their impact on the development of eHealth systems.

Fig. 1. SHARP approach and process

2.1 Motivation and Gap

Due to an ageing population, there is growing interest in long-term sustainable health management and associated systems. This means the system should be sustainable and support patients' sustainability. The focus of individual and family sustainability is on economic, environmental, social, health, and cultural aspects.

Balancing the various dimensions of life (Fig. 2) is a challenging task — especially for ageing and chronic condition patients. Unlike acute diseases, the duration of chronic conditions is often life-long, and patients often face life uncertainties with a great amount of anxiety. Their main concerns are the health issues; however, lost productivity due to their illness and the costs of healthcare easily hurt the financial status of patients and their families and make them more vulnerable to impoverishment [8]. Furthermore, this stress can impact their social and family relationships, which can make their health condition worse.

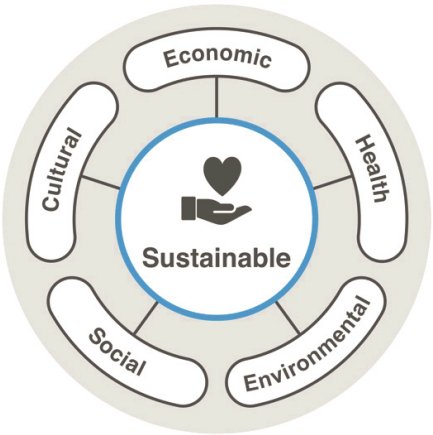

Fig. 2. Sustainability dimensions

The threat of patients' sustainability causes a huge *cost of illness* (COI) burden to our society. For example, the US economy spends $1 trillion annually for the most common chronic illness healthcare [9]. Also, US employers bear a cost of $1,685 per employee annually because of health-related absenteeism [10]. Fortunately, much of these costs are avoidable by promoting and supporting sustainable life patterns for chronic illness patients, and by preventing those who are healthy from falling ill to diseases that could be avoided. Therefore, it is important to provide a health system that can understand an individual's life and support them in a sustainable manner in the different facets of their life: *health, economic, environmental*, *social*, and *cultural*.

SHARP takes sustainability as one of the main concepts and provides insightful information to segments such as ageing, yet-to-age, individuals with chronic illnesses, disadvantaged communities, and patients who have raised expectations of healthcare. As SHARP understands dimensions of individual sustainability (Fig. 3), it will consider

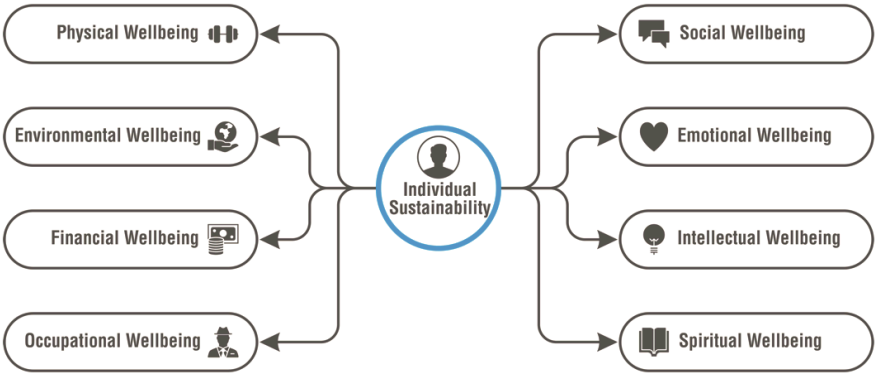

Fig. 3. Factors of individual sustainability and wellbeing

various risk factors related to our life and provide sustainable health advice by connecting individuals, families, and various health providers.

2.2 Holistic

Our life has various dimensions that are tightly intertwined [11]. Understanding their relationship is important to the pursuit of a sustainable life. Dunn [12] asserted the definition of health should not be limited to an absence of illness, but rather looked at as the *integrated being* of an individual that includes body, mind, and spirit.

As such, a health care system should be able to offer an integrated and holistic care approach. *Integrated care* means health systems not only provide clinical treatments, but also take care of the full range of patients' needs from the physiological, spiritual, emotional, and neurological dimensions (Fig. 4). One of the health promotion campaigns in the US adopted a holistic approach to life in their treatment of mentally ill patients; their campaign believes this is the only way to deliver a high-level of wellbeing to patients [13].

As patients are already experiencing some physical limitations, the holistic approach to life can reduce anxiety arising from life's uncertainties.

An effective management of health conditions should extend beyond medical treatment. Therefore, SHARP caters to life dimensions that are likely to impact on one's health condition, and vice versa. It will educate patients and their families on relationships and dynamics of life dimensions by picturing patients' lives as scenarios. These scenarios embrace the concept of the interrelationship of life's dimensions in creating individual sustainability, and thereby help patients learn how one small action can transform the sustainability of their life.

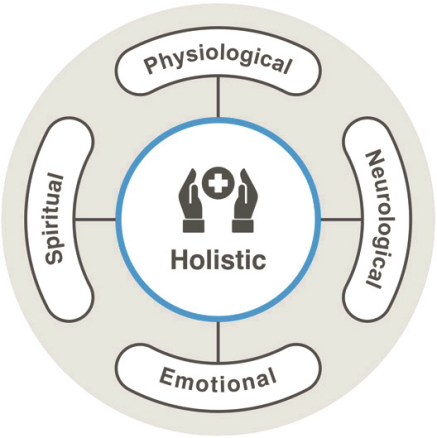

Fig. 4. Factors of holism in SHARP

2.3 Adaptive

Adapt or die is a common phrase one often hears; however, the *way* one adapts is not always clear. When one looks at literature, there are many synonyms as well as phrases that help us to understand what adaptation is, and what is required to adapt — such as learning, being agile, versatile, alive, resilient, and independent (Fig. 5). While these characteristics of adaptation are vital, the process of adaptation is also important.

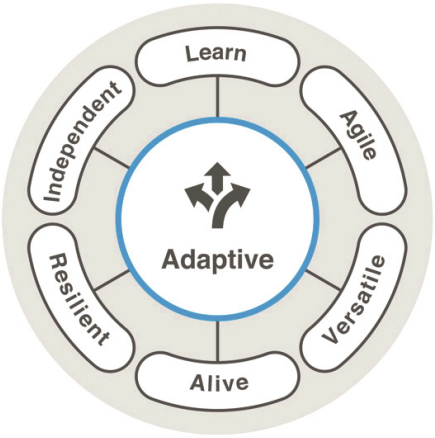

Fig. 5. Factors of adaptive in SHARP

Many processes such as sense-interpret-respond, sense-interpret-decide-act, observe-orient-decide-act, define-measure-analyze-improve-control, and strategize-design-implement-control, have been suggested in literature. At the heart of all of these is the requirement to sense-interpret-decide-act. The SHARP approach and process

embodies, as a whole, an adaptive philosophy that helps the individual, the systems, and the support community around the individual to be constantly learning, alive, and resilient through agility, versatility, and independence.

2.4 Real-Time

A key aspect involving critical or important events is timing. For example, in the airline industry, *timing* is clearly defined: time to check in, time to board, and time to take off. However, the notion of real-time health care services is lacking. The model of healthcare services is designed to be an *episodic intervention* between the individual and health care sector. The individual is expected to visit the doctor when required; i.e., general checkup, vaccination, when sick, and regularly managing long-term disease. The individual is also expected to seek help when it is required; i.e., calling the ambulance, visiting the emergency department, or visiting a specialist.

The SHARP approach involves the use of real-time health services, which are a means of delivering a health intervention at the right time. The SHARP framework considers data latency, analysis latency, and decision latency (Fig. 6). Knowing these parameters and establishing the connectivity amongst stakeholders will enable delivery of the appropriate real-time services. For example, if a system knows the *data* (prescription information of a patient), it will be able to analyze *when* the prescribed *activity* is expected, and as a result, a *decision* might be to deliver a notification using suitable Ubiquitous Information System (UIS) media (see Sect. 2.5).

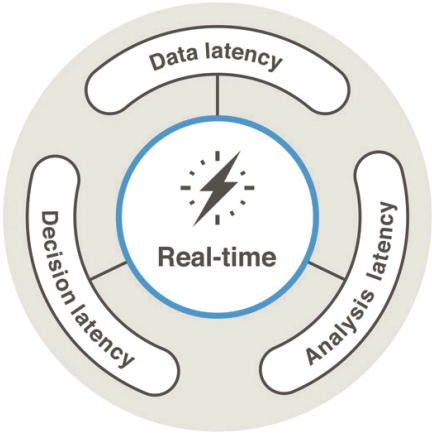

Fig. 6. Factors of real-time in SHARP

UIS technology is useful in delivering real-time contextual health alerts or feedback; many studies often rely on mobile technology or UIS to deliver real-time context-driven health services [14–16]. UIS could also help operationalize decision support objectives for complex disease management such as with diabetes. The study [17] shows a way to manage diabetes that uses an Internet of Things (IoT) approach.

Incorporation of the real-time part of the SHARP framework leads to achieving a proactive non-episodic model of health interventions. The real-time health alerts and feedback could assist in reminding patients of medication and health activities.

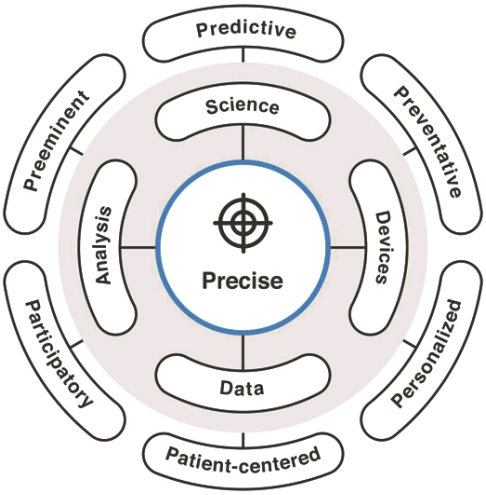

Fig. 7. Factors of precise in SHARP

2.5 Precise

We define *precision health* as the ability to deliver real-time feedback and support for health services tailored to the individual; it involves determining the most appropriate intervention, reminder, feedback, or alert in any given context. There is a variation of terminology between *precision medicine* and *precision health: precision medicine* focuses on clinical contributions; whereas, the notion of *precision health* is broader and focuses on individual wellbeing.

New global initiatives such as [18, 19] are advancing individualized patient care, and extend into university research centers and programs [20, 21], as well as calling for funding proposals [22] and political announcements:

> "I'm launching a new Precision Medicine Initiative to bring us closer to curing diseases like cancer and diabetes — and to give all of us access to the personalized information we need to keep ourselves and our families healthier" — *President Barack Obama [23].*

The notion of precision medicine or health can be further explored from *four* key aspects of the SHARP perspective (see Fig. 7). Firstly, it involves *science,* which is related to the medicine or clinical approaches. This is where studies involve clinical contributions; for example, in [24] the authors apply precision health care in a therapeutic approach to prevention in children's mental health, [25], look at advancing precision medicine for large-scale cancer genomics data, and [26] explain how precision medicine is useful for complex diseases including cancer, genetic disorders, and analysis of

biomedical information including molecular, genomic, cellular, clinical, behavioral, physiological, and environmental parameters.

Secondly, it involves *devices* that use a range of UIS devices and services including mobile devices, mobile applications, web applications, tablet applications, Short Message Service (SMS), Email, mobile notifications, chat and instant messaging, smart watches and health bands, intelligent clothing accessories, IoT sensors and micro controllers, web-based widgets and modules, dashboards, kiosks, and screens. This wide range of channels enables easy delivery of the context-driven, precision health outcomes.

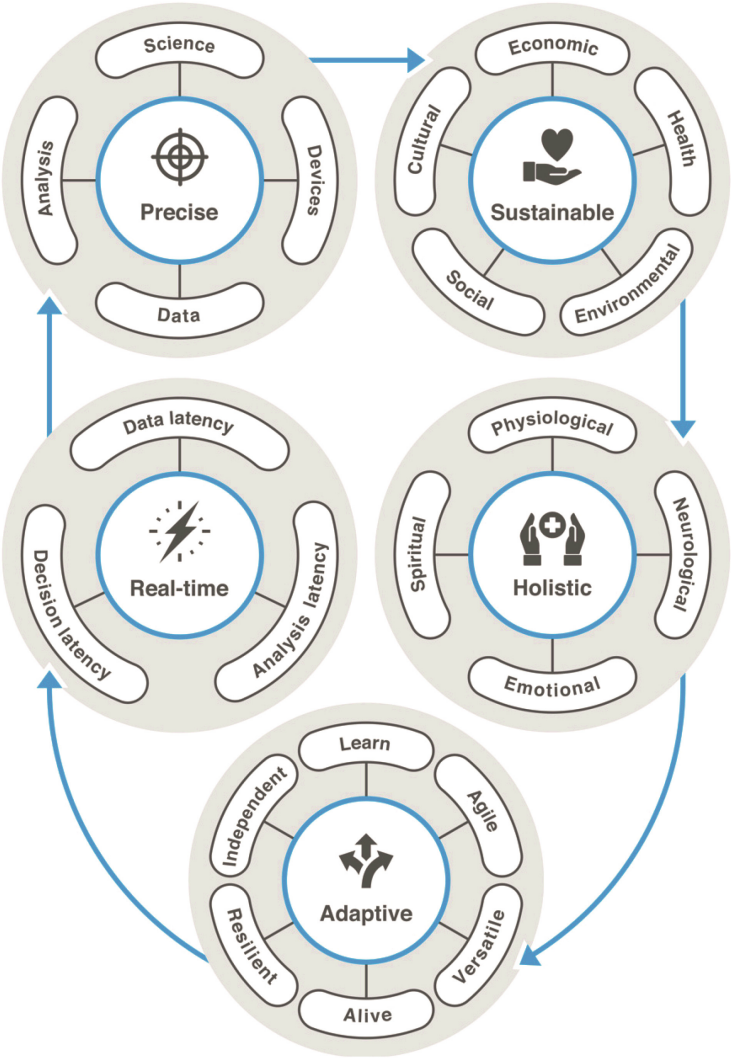

Fig. 8. The SHARP framework

Thirdly, it involves *data,* which is the ability to have *access* to the wide range of sources of data. Each individual's health data can be categorized into bio-molecular data, environmental data, and device data [27]. The bio-molecular data comprises data from exposome, epigenome, microbiome, metabolome, proteome, transcriptome, and genome. The environmental data includes medical, healthcare, biometric information, and scientific records. The device gathers data from wearables, mobile phones, IoT, cognitive analytical platforms like IBM Watson, and other cloud-computing health repositories.

Fourthly, precision health involves *analysis* which reveals insights, patterns, and relationships across data in an effort to deliver the right treatment to the right patient at the right time through early diagnosis and individually tailored treatments.

The above factors can be helpful in achieving *Precision Health* goals that (a) attempt to predict and proactively prevent ill health (b) are participatory and collaborative, and (c) provide personalized patient-centered health care that is pre-eminent [20] and interweaves all the ideas presented in Sect. 2 results in the SHARP Framework (Fig. 8).

3 SHARP Scenarios for Further Research

An estimated one in seven US adults have at least two of five major chronic conditions: cardiovascular disease, cancer, chronic obstructive pulmonary disease, diabetes, and arthritis [28]. Based on the literature in Sect. 2, the article presented how SHARP framework's characteristics can inform, design, and evaluate a comprehensive solution. Healthcare delivery on an ongoing basis based upon the SHARP approach can have a positive impact on an individual's health. A few specific scenarios that are being investigated by the authors of this article using the SHARP approach are presented below.

3.1 Medical Adherence

A shocking statistic published by the Center for Disease Control and Prevention in the US reports that 75 percent of adults are non-adherent with their medications [29]; furthermore, 31 percent of the patients do not adhere to new medications. On the other hand, 89 percent of patients acknowledge their prescribed medication and its medical adherence was necessary for maintaining health [30]. The research [31] reported the estimated annual costs resulting from poor medical adherence is $100 billion in the US and €25 billion in the European Union. Non-adherence can also lead to severe outcomes including deaths; it is estimated that non-adherence to antihypertensive treatment causes 89,000 premature deaths in the US annually [32].

At present, there are many methods for assessing patients' medical adherence [33], identified as: individual self-report of medication taking, real-time electronic monitoring, pharmacy refills, prescription claims databases, and pill counts. These are the most commonly used measures of adherence in research. However, there is no global or national standard for measuring medical adherence [34].

Based on the dreadful statistics above, and the development and adoption of UIS, we are presented with a timely opportunity to contribute solutions. Using the SHARP

approach, the opportunity would first be to remind patients by delivering precise medical adherence interventions, and second, to obtain feedback on whether the medication taken was effective (a step beyond the precise medical adherence reminders). This feedback can be received via a feedback request, and delivered via the most suitable UIS medium. Finally, we can allow the ability to respond to or escalate negative feedback should the medication cause unfavorable results including allergic reactions. The response can be one that is clinical decision supported and delivered in real-time using bots, or involve a clinical intervention depending on the configured scenarios.

3.2 Diabetes Therapy for Ageing Individuals in Ambient Assisted Living (AAL) Environments

The prevalence of diabetes and impaired glucose tolerance is found to be similar for men and women, but increased with age [35]. Diabetes therapy management in Ambient Assisted Living (AAL) environments such as old people's and diabetes patient's homes, is a difficult task because it involves several factors that affect a patient's blood sugar levels [17]. Factors such as illness, treatments, physical and psychological stress, physical activity, drugs, intravenous fluids, and change in the meal plan can cause unpredictable and potentially dangerous fluctuations in blood sugar levels. However, diabetes therapy and treatments provided by physicians to the patients *do not* consider these fluctuations in real-time; this results in dosage inaccuracies in medication and may culminate in hyperglycemia and hypoglycemia episodes [17].

Using a SHARP approach, the development of an artificial intelligence (AI)-based clinical decision support mechanism can assist diabetic individuals with effective decision support. Furthermore, it can recommend precise insulin infusion calculations via an analytics-based intelligent decision support system. This could potentially assist patients with diabetes to regulate the amount of insulin introduced in accordance with their lifestyle and individual inputs. Consequently, it can lead to adjustments in software predictions of insulin requirements, and thus deliver personalized medicine to manage insulin levels for people who are unable to self-manage their disease in AAL.

3.3 Seamless Monitoring in Ambient Assisted Living (AAL)

The role of UIS in AAL environments presents us with an opportunity to achieve a seamless integration of connected sensors and cloud-based data collection possibilities. Using IoT in the personal home environment or care facilities can broaden the sources of *data* that can inform precision health scenarios. Automatic semantic summarization of human activity and detection of unusual inactivity are useful goals for a vision system operating in a supportive home environment [36]. For example, using a weight-sensor configuration embedded in a bed can be helpful in monitoring data and detecting early indications of physical or mental health changes. Other examples include tracking blood pressure, movement activity, or fall detection. AAL highlights technologies that adapt to the user rather than requiring the user to adapt to the technology [37].

Low-cost *appcessories* (including mobile application and sensors) and cloud-based services can be developed to support patients who want to remain in an independent

living environment. It also avoids higher medical costs if conditions are detected at an early stage.

We believe the seamless monitoring approach will be successful as it improves the patient's experience of living independently, and at the same time includes relatives and caregivers delivering a low cost option of a *real-time care solution*.

3.4 Ageing Individuals

Healthy life expectancy increases across countries at a faster rate than total life expectancy, which suggests reductions in mortality are accompanied by reductions in disability [38]. This further suggests that a focus on the reduction of disability due to illness will become a key success factor in aged care and introduces new challenges for ageing populations.

The *new old* have a desire to live independently as long as possible. Since the traditional model of living closely together as a family is vanishing, and assisted care options like rest homes, hospitalization, institutionalization, and retirement villages are expensive options, the ageing individuals can continue to live in AAL with the assistance of *smart* devices. The authors [39] state the concept of the *smart home* is a promising and cost-effective way to improve home care for the elderly and disabled in a non-obtrusive way, and allows greater independence, maintenance of good health, and prevention of social isolation.

Generally, this population represents the future users of the *smart home* approach, provided the devices are effective and easy to use. Ageing individuals are often challenged with long-term conditions, so self-management becomes vital. [40].

The inclusion of multiple care groups; i.e., family, primary care, and secondary hospital, and including the contexts of work, home, and social, will allow development of successful solutions.

3.5 Digital Natives

The authors in [41] present a research commentary on digital natives, claiming their rise, along with the growth of UIS, potentially represents a fundamental shift in the paradigm for information systems research. To manage individuals with fewer health issues who are well-acquainted with UIS is an attractive opportunity to introduce preventative medicine health solutions. The author in [42] presents ways that UIS can expand the range and flexibility of intervention and teaching options available in preventive medicine and healthcare.

UIS can enable the delivery of automated, self-instructional, health behavior change programs through the Internet. Digital natives, having no adoption barriers, can be the biggest benefactors of such solutions. The opportunities for a SHARP-oriented approach with digital natives can involve studies on automated data collection, convenience healthcare, open communication platforms comprising social networks and video, and creation of *information environments* via digital platforms. The focus must extend beyond home and social to also include workplace wellness [43]. Overall, there is some evidence from physical activity self-help interventions that suggests enhancing the

interactivity of intervention delivery increases the sustainability of intervention effects [42].

4 Conclusion

This review argues that traditional models of episodic health care will not be sufficient to meet changing health care needs. Maintaining an individual's health and wellbeing does not solely rely on advancement of clinical treatments and interventions. While these are important, there is now broad consensus that health differences between groups and within groups are not driven by clinical care, but by the social-structural factors that shape our lives [44].

This review presents an approach to pursue systems development in healthcare in a way that considers a range of aspects known as SHARP: Sustainable, Holistic, Adaptive, Real-time and Precise. This approach provides solutions that will be useful and effective for managing the long-term well-being of individuals. Furthermore, potential healthcare *scenarios* and *how* they can apply SHARP are presented. These scenarios include SHARP solutions for medical adherence, diabetes therapy, seamless monitoring, ageing individuals, and digital natives.

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