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# Towards Intelligent, Multidimensional Context-Aware Personalised Healthcare and Wellness Support Services

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**Abstract.** Healthcare and wellness support that consider context within different dimensions can lead to intelligent, personalised recommendations that will more likely be accepted and acted upon by consumers. In this paper, we look at the main components of traditional personalised healthcare and wellness support services, and identify some of the challenges that should be addressed in creating a more intelligent and efficient solution. Our contribution lies in defining a way forward in terms of designing such a solution.

**Keywords.** digital health, personalisation, multidimensional preventive measures, health recommender systems, context-awareness.

## Introduction

An intelligent, multidimensional and context-aware healthcare and wellness support approach is the way forward to more proactively engage consumers in their personal health and wellbeing management. By making it easier and more intuitive to reach better lifestyle choices, personalised healthcare and wellness management can contribute to the reduction of non-communicable diseases and related deaths [1]. In this paper, we present a comparison of traditional and future thinking, personalised healthcare and wellness support services, with the aim of working towards an immersive digital health experience where the consumer feels comfortable and in control of his/her health and wellbeing.

*Digital health* is a term that is often used to reflect the use of new technologies guided and influenced by behaviour change theories (e.g., social cognitive theory, transtheoretical model of behaviour change and health belief model) to support and promote positive health-related lifestyle changes [2,3]. The key element in this transition in the health space is the integration of cutting edge information and communication technologies to accompany and strengthen traditional procedures while enabling advanced, personalised self-management services at different levels [4]. Personalised interventions (e.g., personalised nutrition recommendations) have been proven to be more readily accepted by consumers than the general population-based interventions, resulting in efficiently influencing health-related habits [5]. Therefore, the number of digital solutions

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offering personalised healthcare and wellness support services have increased significantly. This is particularly due to the recent advances in mobile, wearable and Internet-of-Things (IoT) technologies which undeniably established a solid technical ground to facilitate collecting and storing consumer-related health data [6].

Notwithstanding the wide variety of available healthcare and wellness support services and their significant role in educating consumers about their health status, they are still considered powerless in positively affecting consumers' unhealthy habits [7]. Some existing solutions such as Samsung Health[2] and Google Fit[3] provide simple recommendations based on basic collected data (e.g., daily steps count and hours slept), yet changing consumers' lifestyles demands deeper investigations to deliver actionable influencing recommendations. The challenge for promoting healthy lifestyles by generating the appropriate personalised recommendations that can help achieve the desired change is far from just collecting and classically processing consumers' personal information and preferences (e.g., dietary intake, number of steps, mood, etc.).

The objective of this short paper is to review previous related research efforts, present them in a structured manner that simultaneously unveil contributions, limitations and potential lines of improvement for future research. We mainly attempt to merge the existing knowledge in *health recommender systems* as a starting point for a new research direction. This will see the development of a set of innovative decision support tools working collaboratively to intelligently gather and investigate consumers' daily life data, collected from multiple heterogeneous sources to subsequently recommend *just-in-time context-aware personalised, preventive* measures. In contrast with classical recommender systems in which "users" and "items" are the only elements considered in generating recommendations, we propose the integration of *contextual information* such as current location, activity, physical and mental conditions, weather, etc., to play a very decisive role in increasing the trustworthiness, accuracy and acceptability of generated recommendations.

## 1. Traditional personalised healthcare and wellness support services

The personalisation of healthcare interventions is a key driver of innovation for research and for healthcare practitioners and providers alike. Advances in information and communication technologies, especially in recommender systems have crucial implications for the health system, offering new ways of digital health technologies capable of differentiating traditional population-based measures from personalised individual interventions. Below we shortly discuss those basics and why nowadays (traditional) personalised healthcare and wellness support services are no longer considered capable of influencing positive lifestyle changes.

### *1.1. Personalised healthcare*

Personalised healthcare is a pioneering approach that promotes the development of technologies and solutions customised to each person via considering his/her unique genes, lifestyle and individual variability [8]. The ultimate goal is to improve the decision-

[2]https://health.apps.samsung.com
[3]https://www.google.com/fit/

making process associated with disease (prevention and treatment) management, epidemics prediction and life quality improvement, in general. As explained by Allen and Christie [9], there is no widely agreed-upon definition for personalised healthcare, yet there is a common acceptance that this usually refers to the use of wearable devices to monitor consumers' health-related activity and provide feedback at the individual level, either through corresponding with mobile health apps or as a mini-display on a wrist smartwatch.

Information and communication technologies are playing a critical role in accelerating the transition from the traditional approach of generalised population-based towards personalised digital health interventions [10]. For instance, *artificial intelligence* techniques are used to analyse and process terabytes of lifestyle data such as steps walked, hours slept and calories consumed to deliver instantaneous, predictive and tailored measures contributing to empowering behaviour change and self-quantification movement. It is worth pointing out that the successful development and recent breakthroughs in deep learning theory, methods and models have the potential to make a profound impact in preventive and personalised healthcare supporting health practitioners and researchers to achieve significant results in multiple other applications to provide high-quality services and create healthier communities [11].

### *1.2. Recommender systems*

The recommender systems field is an active research area in computer science since the mid-1990s [12]. These information filtering systems have gained popularity ever since and been extensively investigated in a wide range of domains such as e-commerce, social media and advertising, search queries, online dating and life insurance. Several giant companies especially in the e-commerce area, such as eBay, Amazon and Alibaba rely on some specialised recommendation algorithms to efficiently increase their sales. However, recommender system application as healthcare and wellness support services has been overall reported as very limited. Hors-Fraile et al. [13] demonstrated that the use of recommender systems in changing health behaviour is still in its early stages with only a few studies that reported the theoretical factors and behavioural change techniques used as part of these systems. This claim is supported by Schäfer et al. [14] who explained that when it comes to some very sensitive application areas such as the human health and body (e.g., diagnoses, treatments, nutrition and fitness), recommender systems are still far from gaining trustworthiness and reliability. This certainly opens up a set of serious questions about the potential risks associated with the use of recommender systems within the health space.

Nevertheless, there is a common consensus about the potential of recommender systems to deliver highly relevant tailored digital health interventions to each consumer while contributing to reduce the burden they might experience due to the huge amount of available online information [3]. Recommender systems also have the capacity to dynamically evolve with consumers' data which may lead to suggesting personalised recommendations that align with their changing individual preferences.

### *1.3. Context-awareness consideration*

The classical approach of generating recommendations might not be sufficient to deliver what is expected from a personalised healthcare and wellness support service [14]. For

instance, the traditional considered rating mechanism in recommender systems (which relies on the explicit and implicit interactions of the user with the system) is not capable of extracting deeper hidden user's preferences that might change according to his/her current context, raising needs, known and unknown diseases, etc., which may influence delivering accurate just-in-time recommendations that contradict the user's initial preferences (e.g., the user's preference for sugar may contradict his/her need for meals/recipes that align with diabetes).

A significant shift has been noticed in the literature towards *context-aware recommender systems* [16], with proven strong capabilities in adapting to users' changing physical and mental situational needs. Afzal et al. [7] pointed out the necessity of integrating contextual information into physical activity based recommender systems in order to provide reasonable suggestions to the consumer. Also, the authors explained that personalised healthcare and wellness support services need to consider cross-context information where multiple contextual factors (e.g., current location, activity, weather, etc.) should be aggregated to reflect the overall dynamic physical and mental situational context of the consumer.

## 2. Towards the next-generation of intelligent personalised healthcare and wellness support services

In developing the next-generation of efficient intelligent personalised healthcare and wellness support services, many challenges are to be addressed. Firstly, as the primary interest of recommender systems research has been set for years on increasing the accuracy of users' preferences prediction (i.e., perfectly matching real and predicted user ratings for certain items), it is time for new research to address challenges related to both predictions' accuracy and domain-specific problems. Extending the basic capabilities of traditional algorithms with the context-awareness feature is a great opportunity in (health) recommender systems [7,14]. Furthermore, ongoing research to propel more advances in eHealth/mHealth including smartphone apps and cloud-based personalised healthcare and wellness support services will have to deal with some important research questions such as [3,15]:

1. How to increase the level of personalisation and improve recommendations' acceptability without compromising consumers' profiles and preferences?
2. How to enable autonomous just-in-time context-aware personalised recommendations capable of changing consumers' habits?
3. How to deal with the common concern of high dropout rates, sudden lack of motivation and the fact that consumers might not use the interventions as recommended?
4. How to ensure continuous domain experts' knowledge integration in the decision-making process which will subsequently decrease the usual needs expressed by consumers for face-to-face consultations?

This paper reveals an important opportunity for researchers in personalised healthcare and wellness support services which consists of developing non-traditional precision health management solutions that simultaneously (as an ideal scenario) track, manage and improve consumers': i) nutrition quality while enabling adapted diets and healthy

recipes recommendations; ii) physical activity and exercises while coping with nowadays modernised sedentary lifestyles; and iii) mental health and sleep disorders while positively influencing the emotional, psychological and social wellbeing. To the best of our knowledge, most of the proposed context-aware health recommender systems has focused on either diet, physical activity or mental health. The potential of combining these three key health dimensions in the same self-tracking, self-monitoring and self-quantification solution has not been treated yet in the literature [10]. Previous research works have examined interventions using smartphone apps to change consumers behaviour while focusing on one or two of these dimensions without exploring the benefits of combining them together. This can be of great impact as diet, physical activity and mental health are often inter-related and are all required to achieve healthy lifestyle changes. It is what we refer to as a next generation of *intelligent, multidimensional context-aware personalised healthcare and wellness support services*.

It is worth pointing out that some cross-cutting issues in health recommender systems such as risks, security and privacy are other untapped challenges that need further consideration. Last but not least, enabling access for the residents living in the urban or countryside with poor IoT infrastructure is another exciting opportunity for researchers in this field.

## 3. Conclusion

Moving towards intelligent personalised healthcare and wellness support services is the next challenge for researchers in digital health and recommender systems. This transition triggers new research questions that deserve deeper investigations to enable the vision of designing innovative solutions capable of addressing some untapped concerns such as (i) recommendations acceptability; (ii) effectiveness of offered measures in changing consumers' habits; and more importantly (iii) long-term adoption of online personalised services. Building on this, the identified key challenges in this paper offers a set of opportunities towards a next generation of *intelligent, multidimensional context-aware personalised healthcare and wellness support services*.

Finally, the personalisation of digital health interventions raises some ethical issues because of the criticality and sensitivity of consumers data and the continuous concerns about potential cyberattacks on IoT entities used to collect life-logging health-related data. Thus, research efforts in health-related data protection schemes are needed to ensure the success of the next generation of personalised healthcare and wellness support services, in an era where data security and privacy are not trusted and guaranteed.

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