

Just in time Intervention for Personalized Healthcare: Behavior-Context based Intervention Adaptation

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Abstract— Advanced computing has provided the foundation for the self-assessment of lifestyle and change the unhealthy habits. The focus of healthcare industry has been shifted to adopt healthy lifestyle for improvement of life quality and span. Currently, the main concern of the wellness applications is to support user with personalization and self-quantification. The challenge is not only to indicate the unhealthy behavior just in time but also adapt it step-by-step through the realization of behavior change theories. Our proposed methodology focuses on the behavior-context for adopting the appropriate way of intervention for actionable behavior. Initially, lifelog and questionnaire based qualitative assessment of behavior is performed for the identification of behavior-context and status. Behavior-context wise intervention is provided to adapt behavior in actionable manner. The interventions are in the form of personalized education, and context-based just-in-time recommendations with enhanced impact through analysis of unhealthy factors of lifestyle. The healthy behavior index supports the quantifications and mapping of behavior-context and status to drive the interventions along with analysis of the change in behavior. The theory and index related to behavior have enhanced the applicability of wellness management system through behavior status sketching to adopt healthy lifestyle. The results represent that behavior-context based intervention are more responsive and improve the lifestyle.

Keywords— Behavior-context, Just-in-time intervention, lifestyle habits, recommendations, wellness services, non-communicable diseases.

I. INTRODUCTION

The impact of unhealthy behaviors cannot be overlooked in the occurrence of chronic non-communicable diseases (NCDs). NCDs affect people of all ethnicity, regions, countries, gender

and age groups. These diseases are often associated with old people, but according to World Health Organization (WHO) report, 15 million people die every year because of NCDs between the ages of 30 and 69 years [1]. Old, adult, and children are all vulnerable to the risk factors contributing to NCDs, whether from abuse of alcohol, exposure to tobacco, unhealthy diets, and physical inactivity as shown in Table 1. Imbalanced diets and physical inactivity may cause metabolic risk factors like an increase in blood pressure, blood glucose, and blood cholesterol level. These factors can lead to diabetes, cancer, cardiovascular disease, chronic respiratory diseases and obesity which ultimately lead to the premature deaths. It is very necessary to quantify these unhealthy habits to take precautionary measures. Ubiquitous computing has revolutionized the health care industry by shifting the focus towards wellness domain [13].

TABLE I
LIFESTYLE CONTRIBUTORS OF NON-COMMUNICABLE DISEASES

Lifestyle Factors	Diabetes	CVD	Obesity	Metabolic Syndrome	Cancer
Smoking	√	√	√		√
BMI	√	√	√	√	√
Whole Grain	√	√	√	√	
Sugar	√	√	√	√	
Salt	√				
Fruits & Vegetables	√	√	√		
Calories	√	√	√	√	
Physical Exercise	√	√	√	√	√

Lifestyle factors are the very basic and fundamental aspects of daily routine physical and diet portion. Diseases are Diabetes = Diabetes type 2, CVD= Cardiovascular Disease, Obesity= BMI greater than 30; BMI=Body Mass Index, Regular Physical Activity= Moderate to vigorous activity for 25-30 mins per day, Recommended Calories =2000-2500 Cal per day.

II. BACKGROUND

Healthy habits and behavior increase the life span and quality, so person can enjoy more with good health and independent life for long time. The lifestyle behaviors like physical inactivity, alcohol consumption, imbalanced diet, sleeping, stress, and smoking are modifiable.

The regular interrupts of physical activities in prolonged sedentary behavior have good impact on metabolic process [2]. So adapting prolonged physical inactivity behavior helps to improve the lifestyle. Similarly, balanced diet consumption lays foundation of strong body and improve immune system against chronic diseases [3]. The balanced diet is obtained from multiple foods which is essential for the development, protection and survival of vital organs.

Abuse of tobacco and alcohol are two most harmful and dangerous habits which can cause critical health issues that may be life-threatening [4]. The information of adverse impact of alcohol consumption and smoking on the body can stimulate user to avoid them. Context-based behavior interventions are very much desired to support addicted person in a very effective manner [5].

The healthcare and wellness applications usually manages and analyzes the individual's activities log to identify behavior [6]. The trend of reactive approach towards disease management has been shifted to proactive through personalized behavior adaptation. There are multiple behavior adaptation theories to explain the procedure of behavior change. The focus of organizations is to support behavior change by behavior change techniques which target abilities, attitude, behavior-context, environment, and stimulate an individual at right time [7] as discussed in table II. These theories have different prospects and focuses to understand the behavior.

TABLE II.
BEHAVIOR CHANGE THEORIES

Categories	Definition
Theory of planned Behavior	The theory of planned behavior determines an individual's intention of behavior through attitude and subjective norms
Theory of reasoned action	Theory of reasoned action explains that individuals consider the consequences before performing a particular behavior
Fogg behavior model	The Fogg Behavior Model focuses on three basic ingredients of behavior occurs: 1) motivation, 2) ability, and 3) trigger.
Social cognitive theory	Social cognitive theory deals with personal factors, individual ability, and environmental factors.
Transtheoretical model	The Transtheoretical model emphasizes multiple stages of behavior change: 1) precontemplation 2) contemplation 3) preparation 4) action 5) maintenance

*The behavior change technologies and precise explanation [14].

III. PROPOSED METHODOLOGY FOR BEHAVIOR CHANGE

According to the literature, it is necessary to understand and quantify the targeted behavior for analyzing the behavior-context and status of the individual. The proposed

methodology consist of behavior quantification, behavior mapping, intervention selection and feedback processes as shown in Fig. 1. In quantification the individual habits are obtained through lifelog and questionnaire which are mapped to different level of behavior-context to recognize the status of behavior. Finally intervention are generated according to the user context and feedback is recorded for the analysis of the impact of the interventions.

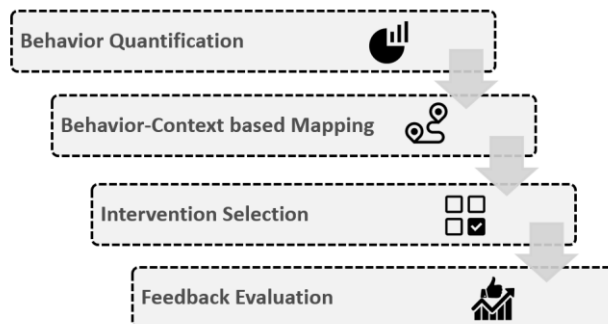


Fig. 1. Abstract idea of behavior adaptation

TABLE III.
QUANTIFICATION OF LIFESTYLE BEHAVIORS

Lifestyle Behavior	Scale	Definition
Diet	1	Imbalanced Diet
	3	Partial Balanced Diet
	5	Well balanced Diet
Physical Activity	1	Sedentary lifestyle
	3	Moderate Activities
	5	Vigorous Activities
Smoking	1	1 and more pack per day
	3	Half to 1 Pack per day
	5	Non-Smoker
Alcohol	1	More than 10 drinks per week
	3	5 to 10 drinks per week
	5	0 to 5 drinks per week

Balanced Diet based on 5 group= whole grains, poultry, dairy, fruits and vegetables, High Salt= more than 2.5 grams per day, High Sugar= more than 40 grams per day; Sedentary Lifestyle= Sitting, Lying, Watching TV; Moderate activities= Standing, Walking, Jogging; Vigorous activities=Running, Swimming, Aerobic; Cigarette Pack= 20 cigarettes.

A. Quantification of the Lifestyle Behavior

The quantification of lifestyle behavior is the foundation of the proposed methodology. The lifestyle behaviors are quantified on the scale of 1 to 5 obtained from the guidelines where 1 show the least and 5 represents the most healthy level of behavior. The four most prominent lifestyle behaviors, physical activity, diet, smoking and alcohol, are considered for the quantification as shown in Table. III [8]. Diet is a composite factor based on multiple sub-components like eating habits, amount of salt and sugar, quantity of fruits,

vegetables, dairy, grains, and red meat. The physical activities are quantified on the basis of the duration, type and level of physical exercise performed in a whole week. The smoking and alcohol quantification depends on quantity of the substance consumed in a unit time.

B. Index Mapping with Behavior-context

The behavior quantification support to generate a comprehensive index based on the contribution of the lifestyle factors depending on the life expectancy impact. Multiple factors have different impact on the overall life expectancy. The smoking is the most important factor towards human health along with balanced diet. The index is based on the summation of all the factors in an appropriate proportion. The index is mapped with the behavior-context level for providing fruitful interventions. The mapping of the index with the behavior- context is shown in Fig 2. We have surveyed the general community people against their healthy behavior index and level of behavior-context and status. We have found out that person with low healthy behavior index (HBI) had less knowledge and information related to consequences of the unhealthy behavior. Similarly the one who had medium level HBI lacking in the support and guidance to adopt the healthy one.

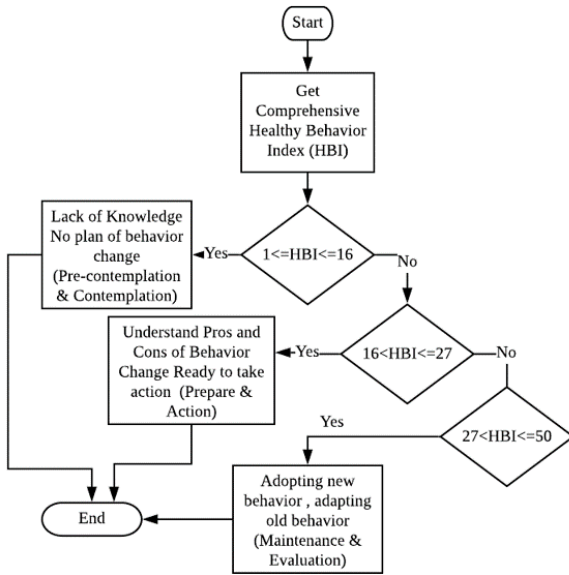


Fig. 2. Behavior-context based Index mapping

C. Intervention Selection

A single intervention is not capable enough to handle different situation of multiple persons’ behavior. Each individual has different level of motivation, abilities, attitude, environment and guidance to adopt or adapt any behavior. Intervention can be prescriptive, informative, cathartic, catalytic, confronting and supportive [9]. The prescriptive interventions support enough to identify the issues in behavior. The informative

interventions educate individuals about behaviors. The confronting interventions help to avoid mistake again. The facilitative type interventions like cathartic, catalytic and supportive boost self-confidence and guide to reach solutions within available resources and facilities. These interventions are mapped with the stages of the Transtheoretical Model (TTM) which is the commonly used model for health-related behavior change [11], [13]. The users are categorized into 3 groups mapped with TTM stages and provided different kind of intervention to adopt healthy behavior. The intervention at different stages are realized through education, recommendations and evaluation as shown in TABLE IV.

D. Feedback Evaluation

We have considered explicit and implicit feedback regarding the intervention. It is quite necessary to evaluate the change in behavior as well as the response against the interventions. The implicit feedback is evaluated on the activity performed by the individual after getting interventions. If the activities after intervention are according to the recommendation it means the interventions are followed positively otherwise the interventions are considered unresponsive. The explicit feedback is collected through survey and questionnaires to evaluate the individuals’ satisfaction regarding the interventions and their applicability

TABLE IV. MAPPING OF TTM STAGES WITH PROPOSED STEPS

Sr. #	TTM Stages	Intervention Processes	Proposed Methodology
1	Pre-Contemplation & Contemplation	Education, Consciousness raising, Risk Assessment	Registration, Question & Answer, Lifelogging (Stage I)
2	Preparation & Action	Focus important Factors, Support for behavior change, Guidance, Stimulus, Dealing with Barriers, Self-assessment	Unhealthy behavior, Indexing to quantify behavior, adaptive interventions, personalized recommendations (Stage II)
3	Maintenance & Evaluation	Reward for Success, Assessment, Support to maintain behavior, Encourage to enhance.	Observe the adapted behavior without any intervention, Evaluate the change in behavior (Stage III)

IV. REALIZATION OF METHODOLOGY WITH WELLNESS MANAGEMENT PLATFORM-MINING MINDS

The realization of methodology requires a wellness platform which can be used to map different stages with selective interventions to involve the individuals. We have selected an open source wellness management platform “Mining Minds” (MM) [10], [12]. It is a multilayered platform with the focus of data curation, context curation, knowledge curation and service curation. The data is generated from multiple sensors of smartphone, smartwatch, depth camera

and kinect. The data curation layer (DCL) manages the raw sensory data and communicates it to information context layer for the identification of low level and high level context form the raw sensory data. The DCL curates the raw sensory data along with recognized context which is used for further analysis and monitoring of activities. The monitoring of recognized activities helps to identify the unhealthy behavior of the individual. The curated data has a complete log of the activities, demographic information, preferences and health record. The pattern of activities at specific time support the implicit feedback identification for the analysis of the effectiveness of the interventions. Similarly, the quantification of the lifelog data on the basis of the behavior supports to generate index to represent status of lifestyle and behavior. So the DCL not only supports to quantify the behavior but also helps to generate index.

The generated index is governed by the expert driven rules which categories the ranges of the index on the basis of constitutes components. As, 10 factors of diet has to be quantified related to regularity, balanced diet, sugar, salt, fats, proteins, grains and dairy. The knowledge related to quantification is managed by the knowledge curation layer (KCL). It manages the rules which are responsible to transform the contributing factors under the impact of demographic, preferences and health based constraints. KCL

also manages those rules which are used to build recommendation on the basis of the specific situation based on the contributing factors of diet, physical activities, smoking and alcohol. The refinement and generation of interventions are governed by the expert mentioned rules.

There are multiple types of interventions and the decision regarding the intervention is provided to individual as service. The service curation layer (SCL) is orchestrating the required services to the individual on the basis of behavior context, preferences, and situation. The individual at pre-contemplation and contemplation level are provided with informative and prescriptive type of interventions. These interventions consist of educational material to enhance and prepare the individual to understand the pros and cons of the unhealthy habits. The unhealthy habits are identified from the quantification of behavior through HBI which highlights the unhealthy behavior of the individual. The interventions are refined and generated on the basis of these identified unhealthy behaviors. These interventions are provided at regular interval for an appropriate time and measure the impact through HBI which indicate the change in adaptation of the behaviors.

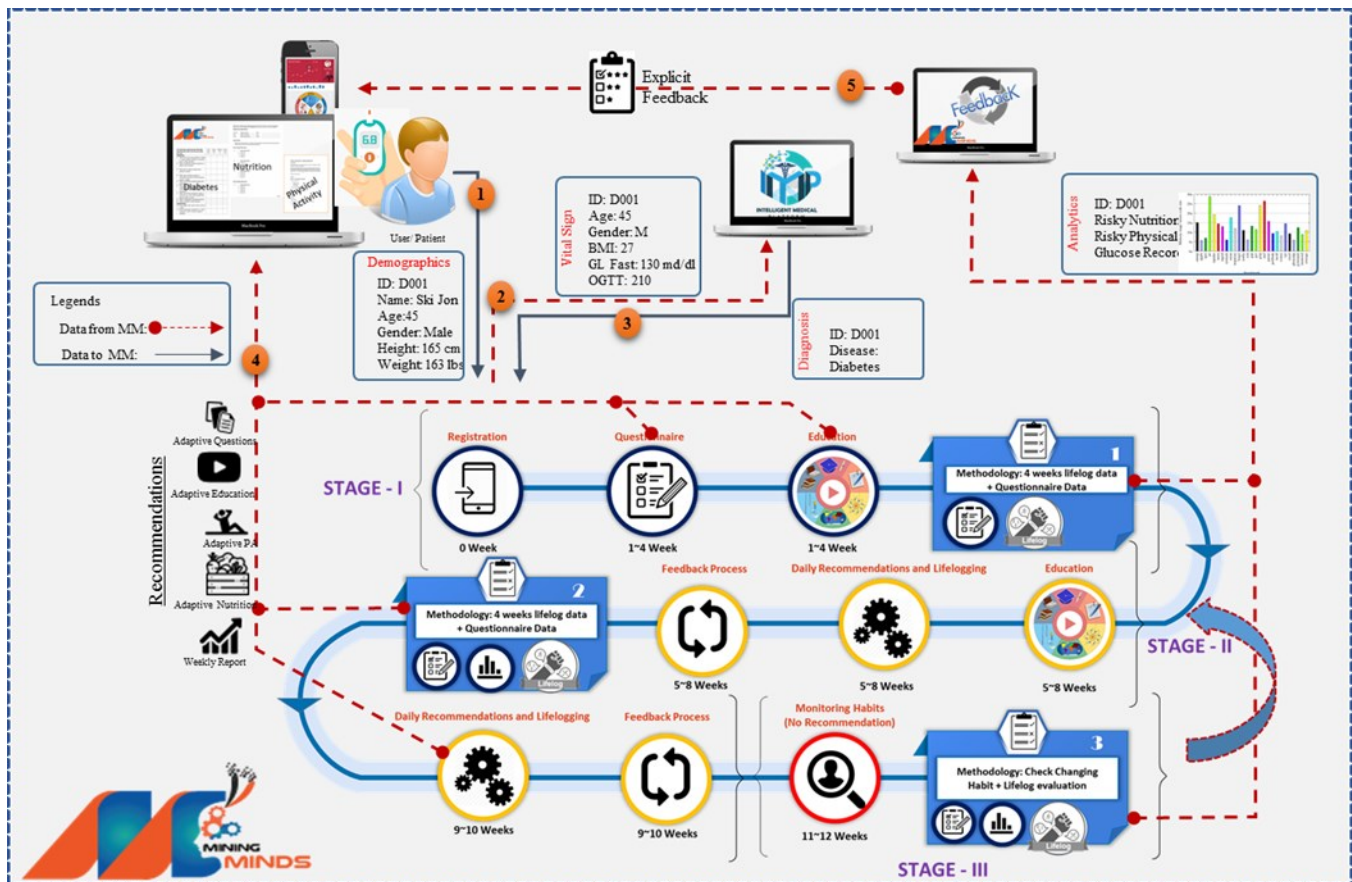


Fig. 3. Methodology realization for behavior-context based intervention

The individuals who are prepared and doing actions require intervention which guide them how to perform those recommended actions to attain the desire behaviors. So the SCL refines supportive and catalytic interventions based on the personalized requirements and preferences. These intervention are provided just-in-time to attain maximum effectiveness. These interventions are provided for a time period of more than month to change in the behavior with proper guidance. SCL also manages the evaluation of behavior through explicit feedback in the form of questionnaires. The selection of questions are based on the HBI status which indicate unhealthy behaviors. These questionnaires are generated at regular interval of time to complement the status obtained from the lifelog.

The supporting layer (SL) manages the interaction with the individuals and provides adaptable interfaces to the users. These adaptable interface consider the medical disabilities, and user interface preferences. It facilitates the visualization of analytical results to understand the situation and condition of the behavior. It also supports the experts to access and analyses the impact of interventions and rules.

V. DISCUSSION & EVALUATION OF METHODOLOGY

The methodology is realized through three stages with the help of open source Mining Minds platform. The duration of stage 1 comprises of total 4 weeks where education is provided on daily basis keeping in view the behavior-context and index. After 4 weeks, there is an explicit feedback through adaptive questionnaire. In the 2nd stage, individuals are provided with just-in-time recommendation for the smoking, alcohol, diet and physical activities. These interventions are indicated to the individuals three times a day to direct about the diet and physical activities status and goal for 6 weeks. In the last stage, evaluation of the behavior is performed without guidance and support. It indicates the adoption of behavior for final analysis and decision.

For evaluation of the methodology we had provided the intervention services to 106 person who were registered with wellness support provider organization. These people were from adult age group with no physical disabilities and have medium level expertise to use smart phone.

At the pre-contemplation and contemplation level, informative and prescriptive interventions are provided to the individual to enhance knowledge about the personal behavior. These interventions had an impact of behavior adaptation of about 68%. The behavior adaptation due to supportive and catalytic interventions at preparation and action stage had an impact of more than 89% to adopt healthy behaviors. At the last stage of evaluation and maintenance, without any interventions, analysis of the behavior adaptation and practice of healthy behavior retention was about 79% which is more effective as shown in Fig. 4.

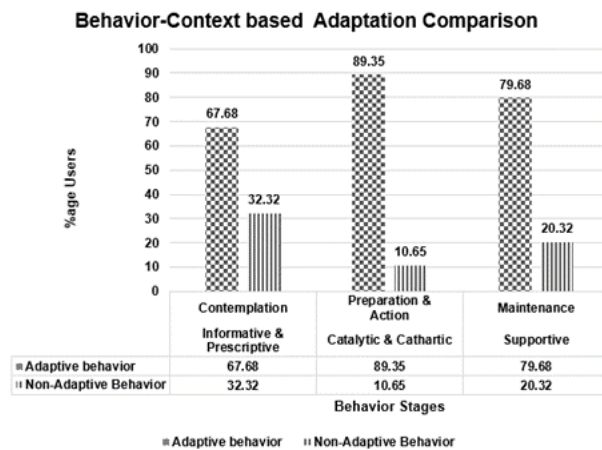


Fig. 4. Comparison of behavior adaptation stage wise

VI. CONCLUSION

We have utilized the transtheoretical model for behavior adaptation along with specific intervention style. The proposed methodology highlighted the importance of intervention style while adopting the healthy and adapting the unhealthy lifestyle. The open source wellness platform is utilized to realize proposed methodology to intervene on the basis of behavior-context and specific intervention style. The result shows that informative and prescriptive interventions have supported many users at initial stage to understand and comprehend the pros and cons of unhealthy behavior. The evaluation shows because of our methodology nearly 78% persons have improved their about 87% of behaviors. In future we want to improve our methodology to support the users to retain healthy lifestyle against addictive unhealthy habits.

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