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Design of a feedback intervention to increase travel related physical activity of CVD patients

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Abstract

Cardiovascular disease (CVD) patients benefit from an active lifestyle with a certain level of physical activity. Assessing the physical activity level of patients in an objective manner can be problematic. Self-reporting tends to be biased and lack of therapy adherence has a negative influence on managing disease risk factors. In this paper we propose a digital framework which collects the level of physical activity of CVD patients with an app and processes this data to obtain an objective measure of physical activity, which is visualized in a dashboard available for the caretakers. By exploiting behavioural theories and combining them with this objective measure of physical activity, patients are classified according to their attitude towards active travel behaviour. Based on this knowledge, caretakers can propose a more active lifestyle to patients by identifying opportunities in making the daily trips of the patients more active. For example, short distances done by car can be suggested to be replaced by walking or biking. The behaviour theories also allow to assess the risk of not adhering to the prescribed therapy. This tool will help in providing a more tailored care and approach to persons with CVD.

Keywords: Travel related physical activity, feedback intervention, behavioural intervention, active lifestyle

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1 Introduction

Cardiovascular diseases (CVDs) are a top cause of mortality in the world as shown by World Health Organization statistics. CVDs are responsible for 31% of all global deaths [1]. CVDs add a considerable economic burden on society; in 2009 they amounted to 9% of all healthcare expenditure in the European Union (EU). The prevention of CVDs can be achieved through either the implementation of lifestyle changes or the use of medicines. Management of the risk factors (low physical activity, smoking, high blood pressure, cholesterol etc.) significantly reduce the mortality caused by CVDs [2]. However, non-adherence to the treatment suggested by practitioners leads to poor management of the risk factors and higher mortality rate. This study focuses on physical activity (PA) level as the fourth largest risk factor. Many studies have proven the positive effect of PA on cardiovascular health [3]–[7]. Hamer and Chida's (2008) study determined the significant association between active travel (use of cycling and walking during daily trips) and reduced risk of cardiovascular events [8]. A systematic review of thirty studies has concluded that despite the use of various methods of Health Impact Assessment (HIA) the net health benefits of Active Travel (AT) are substantial irrespective of the geographical context. HIA refers to estimated health benefit-risk or benefit-cost analysis [9]. Besides, physically active people are less prone to disease and depression and have a lesser rate of smoking and substance usage. Their life expectancy is longer and they are capable of functioning better both at home and at work [10].

There is a huge potential of improving the level of physical activity during the routine day-to-day displacements made by CVD patients. In order to improve the use of active transport modes in the daily travel pattern we are designing an intervention scheme for CVD patients. The purpose of this paper is to describe this intervention design and the analytics of the intervention design. In order to make an informed decision about the most appropriate treatment, calculation of the physical activity level corresponding to the use of active transport modes while making trips is needed. Based on this, the practitioner can identify and recommend alternative active mode choices depending on certain assumptions. He can also assess the current therapy adherence and make adjustments to the therapy as needed.

This paper is organized as follows: Section 2 provides an overview of the types of intervention designs used in health as well as in transportation sciences. Section 3 describes the research project as a whole. Section 4 details the design process for intervention. In section 5 we conclude the paper with some future prospects for the study.

2 Types of intervention designs used in health and travel studies

The word intervention is defined in the Cambridge dictionary as the deliberately taken action to involve in a difficult situation to improve or avoid it from getting worse (www. dictionary.cambridge.org). Relevant examples of difficult situations are bad health behaviours such as alcohol abuse, extensive smoking, low level of physical activity, communicable or chronical non-communicable diseases, and in general all unhealthy conditions. In consequence of these health conditions practitioners or healthcare providers try to either improve the health condition or manage it to avoid from getting worse. Some diseases need medical intervention through surgeries or medication and others benefit from a lifestyle change. Some diseases require both types of interventions in order to be prevented or managed. The use of interventions is not restricted to the healthcare domain but is useful in other professions. In the field of transportation sciences, researchers try to reduce excessive car use and promote public transport. On the cross-section between health and transportation, interventions are proposed to promote the use of active travel modes for shorter trips in order to improve health conditions and environment sustainability. Changing the human lifestyle is not easy and in order to change pre-developed behaviours and habits many interventions use different psychological theories (Theory of Planned Behaviour (TPB), Trans-theoretical Model (TTM), Health Belief Model (HBM)). It is not necessary that every intervention design automatically provides the required health outcome. The effectiveness of the intervention depends upon how they are implemented and on the type of behaviour to be changed. In this section we describe examples of intervention in healthcare and transportation, specifically related to changing active travel behaviour.

The literature is flooded with many kinds of interventions designed in order to impact specific health-related behaviours. One study [11] investigated periodic messaging intervention across health behaviour. The analysis of 42 studies found that periodic messaging intervention delivered through text messages, email, mailed communication or in some cases via phone yielded significant outcomes in inducing health behaviour change. Another meta-analysis investigated the intervention for weight loss in overweight and obese adults. The intervention provided personalized feedback. The study concluded that personalised feedback can prove an important Behaviour Change Technique (BCT) to be incorporated in internet-delivered interventions. The meta-analysis of studies revealed no significant difference between the intervention and control groups [12]. Providing feedback alone for different health behaviour has been found consistently not effective especially in improving physical activity level [13], [14] although the effectiveness of the intervention can be enhanced using BCTs. The effectiveness of internet-based intervention can be optimized by enhancing the design by combining self-assessment or monitoring with tailored feedback [15].

Until now, the integration of health and mobility has been rather limited in exploring the health impacts of active transport modes especially for target groups such as CVD patients. A study investigated a novel ICT- based method embedded with the trans-theoretical stages of change model in order to promote following behaviours: 1) reduced contribution to air pollution emission, 2) increased PA level by active transport mode choices and 3) reduced exposure to air pollution through route planning. The study concluded that there is a wide potential to make people aware and guide them towards healthier and sustainable behavior through the use of advanced ICT methods and personalized feedback intervention [16]. Another study worked out a cost benefit analysis of active travel intervention on health and pro-environment studies. The interventions were introduced by investing in the development of cycling paths, other walking and cycling facilities, huge media campaigns and events to promote the concepts of "share the road" and "shared spaces" and cycle skills training. The study concluded the positive return on health (cardiac disease, diabetes, cancer, and respiratory disease) and reduction in transport related carbon emissions by investing in active travel in a city [17]. Another ongoing research topic in the field of transportation is the promotion of Active School Travel (AST) among children and adolescents as this is the appropriate age for developing life-long behaviours. A systematic review of literature investigated AST interventions in order to assess the quality of the study and theories used. The study found that given that change is inevitable once interventions using socio-psychological theories are designed, but the lack of appropriate use of theories, weak methodological design and lack of reliability and validity of objective measures were identified as main issues [18].

The effectiveness of different intervention designs varies widely but it can be optimized by adding different reinforcers of behaviour change (motivation developing, attitude building, fiscal returns, environmental or infrastructural changes etc.). Our study uses feedback intervention which is embedded with psychological theory and TTM stages of change. Every component of the feedback intervention is carefully designed corresponding to the stages of change (section 4.1). In this paper, we focus on the analytical-computational parts of the feedback report.

3 Travel behaviour monitoring of CVD patients

Our study aims to monitor and collect travel behaviour patterns of CVD patients. In a first stage, we will monitor and collect the data of CVD patients using a smartphone app called HTB (Health for Travel Behaviour). The framework of this study is described in [19]. This paper adds to the framework by providing the details about the intervention component (feedback design) which supports the increase of travel-related physical activity. The app (Figure 1) is designed to collect the daily activity data from patients. We have fixed the monitoring period to three weeks, which balances convenience for the participants and gathering enough data for our purposes. The study plan for monitoring the travel data has been submitted to relevant ethical committees and the documents are under process to fulfil GDPR requirements. Study participants will sign an informed consent before collecting their data. The proposal for intervention stage will also be submitted to the ethical committees before starting the implementation. The HTB app is connected with a third party API of Journeys by Sentiance which collects the sensor data information and sends the processed data to HTB. HTB presents the data of daily activities and asks from the user to annotate three attributes of travel behaviour: 1) motorised transport modes (car, bus and train etc.), 2) travel partner during the trips (spouse, friend and sibling etc.) and 3) activity purpose (shopping, work and social activity etc.). Possible errors in transport mode recognition by the Sentiance data processing are covered because the user has the ability to annotate the trip schedules further in HTB. The data collected consists of the following travel behaviour attributes: a) Number of trips travelled on each day b) Type of transport modes used for each trip c) The purpose of each trip during the day d) Start and end time of each trip and activity e) The destination location for each activity f) The traveling partner for each trip h) distance travelled by each transport mode. Travel behaviour data is analysed and an objective measure for physical activity level is calculated (*Analytics engine*).

Besides the above mentioned travel behaviour attributes, an online survey is also designed to collect socio-demographic information, personal attitude and behaviour towards the use of active transportation and stages of change questionnaire. Socio-demographic information consists of personal and household income, education, age gender, professional activity, frequency of use of different transport modes, availability of number of vehicles, bikes, driving licence. The attitude and behaviour survey consists of questions related to psychological constructs of behaviour such as attitude, perceived behaviour control and social norms based on the Theory of Planned Behaviour. In order to group the participants in their relative stages of change, we propose to use the short version of University of Rhode Island Change Assessment (URICA) questionnaire (*Survey* and *Context*). The data will be stored in a database in a secure data repository. The database resides in a private cluster only accessible by the CTASS service, and personal data is scrambled such that measurement data cannot be linked to specific patients. A final part of designing an intervention to influence the travel behaviour, the designing of the feedback report (*Report Generator*) for the patients after the monitoring period is an inevitable step. Feedback about PA of patients is also visualized for the caretakers in a *web-based dashboard*.

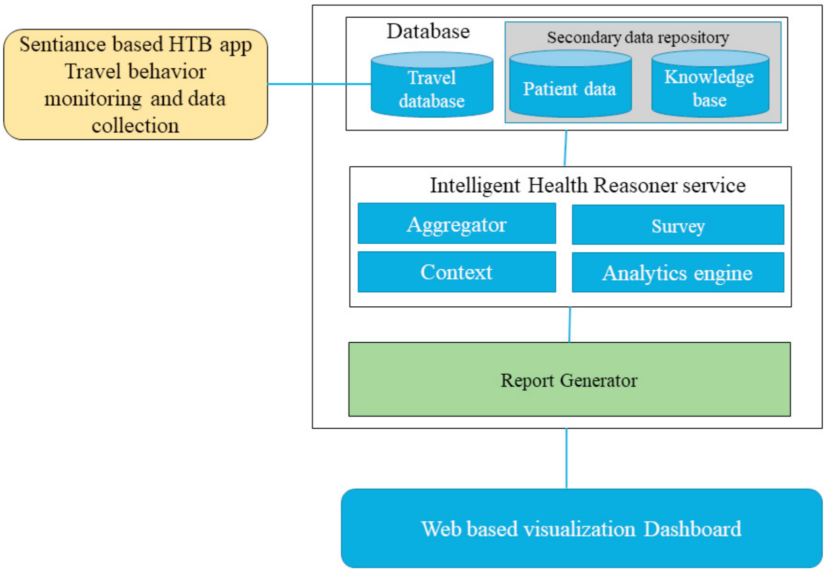

Fig. 1 Cardiac Travel Advise Support System (CTASS)
Source: [19]

4 Designing feedback to influence the travel behaviour of CVD patients

IT-based behaviour change interventions are used to monitor health parameters and serve as the bidirectional benefits to the health practitioners as well as to the patient. In this study we plan to provide a feedback report to the CVD patients on their travel behaviour performance of three weeks as an extension of the Health for Travel Behaviour framework CTASS [19]. Before designing an automatic feedback application we need to confirm that the feedback we design will improve the travel related physical activity. In a first stage, the feedback report, which is generated semi-automatically (not on the HTB app yet) and consists of several components based on behavioural change theories, will be send to pilot test users (we aim to recruit at least 100 patients). The content of the feedback reports is explained in the following sections.

4.1 Contents of the feedback report

The content of the feedback report is designed using the classic Trans-theoretical Model (TTM) stages of change. TTM suggests the *change* as a process which improves over time and the is non-linear. The model define this process in 5 stages of changes which defined in the following points. Each component is designed carefully according to a stage of change [20]. The strategies used for each stage are described below:

1) Pre-contemplation: refers to the stage where the participant has no intention to change his/her behaviour within the next 6 months
    - Change strategy: The participants will be provided some factual information on benefits of using active transport modes and on the consequences of using the car in order to avoid unnecessary use.
2) Contemplation: participants interested in changing their behaviour or taking action within at most 6 months.
    - Change strategy: providing extensive pros and cons of using active transport modes to the participant and leave the decision making to them.
3) Preparation: In this stage the participants intends to finally change their behaviour in a very short period of time (within one month).
    - Change strategy: Supporting participants in setting goals for changing their behaviour towards increasing their travel-related physical activity.
4) Action: In this stage the participants have already taken action to change their behaviour at least 6 months.
    - Change strategy: Providing feedback on travel related physical activity using the data from the previous monitoring period. Encouragement through reward and scores system. Help resolving the barriers by identifying problematic trips routine. Asking for social support is also part of the action stage feedback
5) Maintenance: In this stage participants have already changed the behaviours for more than 6 months.
    - Change strategy: Maintenance stage is out of scope for this study because of its experimental nature and no long-term follow-up plan. We are managing to include the feasible matching strategies for this stage, considering gamification (virtual rewards) and competition among the participants.

The above mentioned feedback plan is a brief description of the process of behaviour change theory. The feedback plan of the intervention consists of few fixed components for every participant such as providing factual information, pros and cons of using active travel modes, goal setting as the theoretical constructs of TTM. The other components of the feedback report are calculated based on personal performance such as calculating the physical activity level and suggesting alternative trips which leads to providing rewards and encouragement based on their feedback performance. The remainder of this paper focuses on calculating the feedback performance based on travel behaviour data and identifying the trips with potential physical activity.

4.2 Calculating the feedback performance

Feedback performance consists of the following summary variables of the travel behaviour for each week (monitoring period).

Table 1 Weekly feedback performance of cardiac patient

Time	40 min	30 min	5 min
Distance	3.5 km	8 km	1 km
Trip count	4	3	2

Travel behaviour data will be collected for three weeks. The above table provides an illustration of the information on duration spent, distance covered and total number of trips by each active travel modes (walking and cycling).

Weekly metrics walking (example): Time = $\sum_{i \in I_7} t_{i\ (w)}$, $t_i > 5$ (1)

Distance = $\sum_{i \in I_7} d_{i(w)}$ (2)

Trip count = $\sum_{i \in I_7} n_{i(w)}$ (3)

Except this overall weekly performance, we have developed a scoring system, Active Travel Score (ATS) based on the physical activity gained by using active transport modes in patients travel pattern. ATS is defined as the physical activity gained by using active travel modes during the week. Physical activity is defined in terms of energy cost as a multiple of resting metabolic rate that refers to metabolic equivalent (MET). MET is defined as 3.5 ml oxygen $[O_2]$ per Kg of body weight per minute consumed while sitting in rest position. The energy cost of physical activity is measured by multiples of these resting metabolic rates [21]. The METs values used from the Compendium 2011 in the study are:

Table 2 METs values corresponding to the active travel modes (compendium 2011)

Code	METs	Transport modes	Average speed (mph)
01018	3.5	Bicycling	5.5
01019	5.8	Bicycling	9.4
01020	6.8	Bicycling	10-11.9
01030	8.0	Bicycling	12-13.9
01040	10.0	Bicycling	14-15.9
01050	12.0	Bicycling	16-19
01060	15.8	Bicycling	>20
16060	3.5	Walking for transportation	2.8-3.2

MET has a dimension of power/mass 1 $MET = 1.\frac{Kcal}{hour.kg}$ which is (more or less) the power consumption per unit mass for a human at rest. The required energy consumption (effort) for a healthy life as per standards are suggested as:

a) 5[days/week] 30 [min/day] moderate MET (MET^m)
b) 3[days/week] 20 [min/day] vigorous MET (MET^v)

where MET^m means moderate effort and MET^v means vigorous effort. We know from the Physical Activity Compendium [22] that,

a) $MET^m \approx 4.0 \frac{Kcal}{hour.kg}$, and
b) $MET^v \approx 10.0 \frac{Kcal}{hour.kg}$

Then the weekly effort requirement is:

$$X^m \approx 5[day/week] * 0.5[hour/day] * MET^m$$
$$= 4.0[hour/week] * 2.5\ [Kcal/(hour.kg)] = 10[kcal/(week.kg)]$$
$$X^v \approx 3[day/week] * 0.333[hour/day] * MET^v$$
$$= 1.0[hour/week] * 10.0[Kcal/(hour.kg)] = 10.0[kcal/(week.kg)]$$

So we assume that the weekly requirement (at both moderate and vigorous rates) approximates $10.0[kcal/(week.kg)]$. Hence, we assume operating modes can be interchanged as long as the total effort over a week is sufficiently large. In the project, the MET values for both walking and biking are taken from the Physical Activity Compendium. Only trips having a duration that exceeds 5[min] are considered. The duration of 5 minutes is chosen due to the fact that effective physical activity duration should be in sessions of at-least 10 minutes each as per literature [23]. In this case we are considering 5[min] as a one way trip. Such 5[min] walk trip corresponds to $1/12 *$

$2.5[\frac{kcal}{hour.kg}]$. Let v_i and d_i be the average speed and the duration respectively of trip t_i and let m_i be the corresponding mode. Let MET(m_i,v_i) denote the MET value derived from the Physical Activity Compendium (see Table 2). Then the requirement for the patient for the last 7 days (the requirement is specified for a week) is:

$$ATS = \left(\sum_{i \in I_7} d_i * MET(m_i, v_i) \geq 10\right) \wedge (\forall_i \in I_7 : d_i * MET(m_i, v_i) \geq 0.2) \quad (4)$$

Where I_7 is set of trips in last 7 days. The standard METs values for cycling, walking and running for travel purposes are used from the 2011 compendium of physical activities [22].

We have also planned to identify the trips which have potential to gain travel related physical activity. The output of this section is designed to be presented as an example (Table 3):

Table 3 Recommendation of replaceable trips into active travel modes

Total number of trips week1	**11**		**Remarks**
Number of car trips by distance that should be changed into walking	3	Trip to service activity on Tuesday	You can easily change these trips by foot as the distance to the utilities is coverable by foot in order to increase your travel-related physical activity level
		Trip to exercise and training on Sunday	
		Trip to social activity on Friday	

The replaceable trips will be selected from the participant's travel behaviour pattern of three weeks based on the decision rules and participant survey data. For example a suggestion will be made for changing the transport mode of a trip into walk or bike if the distance is smaller than 3 km for walk and 3 to 15 km for bike. These distance limits are taken from the average walking and biking trips of general population from literature but we will tailor the maximum or minimum according to the capacity of the patient and the recommendation of the doctor. The algorithm will also check hard constraints by inferring from the survey and context whether the patient is able to walk or bike. The participant's preferences will also be taken into consideration to suggest alternative trips. For instance if a participant prefers using active travel modes for the social activities then the suggestion preferences will be given to the social activity for the specific participant. The algorithm to suggest alternative active travel modes is currently being refined.

5 Conclusions and future work

Given active lifestyle is key to reducing health risks for CVD patients, this study proposes a framework to increase the potential travel-related activity. Non adherence to the PA level in CVD patient increases the risk of mortality. We propose an objective metric for PA which should reduce or at least detect non-adherence to therapy. The framework proposes the objective monitoring of the CVD patients using a smartphone app and a feedback report prepared using the TTM which defines the change as a managed process. The intervention will be tested with CVD patients in order to observe change in their trips routine whether they used active transport or not. In the future we plan to also extend this feedback to be included in the HTB app itself.

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