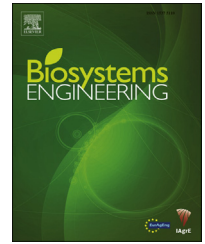


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A smart mirror to promote a healthy lifestyle



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ICT solutions to foster behavioural change have been shown to be effective in implementing primary prevention in terms of a healthy lifestyle. Primary prevention is the most viable approach to reduce the socio-economic burden of chronic and widespread diseases, such as cardiovascular and metabolic diseases. In this paper, we present a novel multi-sensory device, the Wize Mirror, which is under development in the EU FP7 Project SEMEOTICONS. The Wize Mirror detects and monitors over time semeiotic face signs related to cardio-metabolic risk, and encourages users to reduce their risk by improving their lifestyle.

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0. Introduction

It is well-known that prevention is the best strategy to limit the spread of cardio-metabolic diseases, which are the leading cause of mortality worldwide (Mathers, Fat, & Boerma, 2008). Indeed, cardio-metabolic risk factors are mainly related to modifiable factors pertaining to people's lifestyle, such as dietary habits, physical activity, tobacco and alcohol use, stress and psychological conditions. New perspectives on primary prevention rely on the empowerment of individuals, in terms of their ability to self-monitor their health status and act upon their lifestyle. Nowadays people are aware of the importance

of a correct lifestyle, and they want to be active actors in the acquisition and maintenance of wellbeing.

Over the last few years, supportive technological instruments have invaded the market, mainly in the form of wearable devices (wristbands, smartwatches, eyewear, wearable bio-monitors) and applications on smart devices (such as Runtastic or Melarossa). According to an Internet-based survey of thousands of Americans (Ledger & McCaffrey, 2014), in September 2013 one in ten US consumers over the age of 18 owned a modern activity tracker. Interestingly, there was a bimodal distribution of users by age: the adopters are divided into youngsters (25–34 years), who focus on fitness optimisation, and older users (55–64), who focus on improving overall health and extending their lives.

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Nomenclature

AGE	advanced glycation end-products
ECG	electrocardiography
EEG	electroencephalography
EMG	electromyography
HUI	health utilities index
HRQOL	Center for Disease Control and Prevention's health-related quality-of-life
NIR	near infra-red
PGM	personalised guidance module
PGS	personalised guidance system
PSS	personalised support systems
LCD	Liquid-crystal-display
LED	Light Emitting Diode
SEMEOTICONS	SEMEiotic Oriented Technology for Individual's CardiOmetabolic risk self-assessmeNt and Self-monitoring
SF12-PCS	Short Form12 – Physical Component Summary
SF12-MCS	Short Form12 – Mental Component Summary
UV	ultraviolet
VIM	Virtual Individual Model
WI	Wellness Index
WM	Wize Mirror

But what contrasts with the increasing adoption of wearables is that the majority of consumers stop using the device within six months of receiving it. In other words, most of the devices on the market fail to drive long-term, sustained engagement. As a consequence, they fail to make a long-term impact on their users' health.

We believe the key to success is sustained engagement, based on the promotion of behaviour change towards *wellness* as a whole and long-term health objectives. Enhancing wellness is an effective way to promote participation and motivate people to change their habits. In a year-long research study from the University of Michigan (Segar, Eccles, & Richardson, 2011), participants who adhered to a long-time exercise regime did not want to lose weight, but rather to “enhance their daily life and wellness”.

This is the direction in which the European project SEMEOTICONS (“SEMEiotic Oriented Technology for Individual's CardiOmetabolic risk self-assessmeNt and Self-monitoring”) is moving (SEMEOTICONS FP7 European Project, 2013). SEMEOTICONS started in November 2013 to develop a multisensory device in the form of a mirror, called the “Wize Mirror”, which comfortably fits the home as a piece of houseware, but also pharmacies and fitness centres. By analysing data acquired unobtrusively via a suite of contactless sensors, the Wize Mirror detects on a regular basis any physiological change relevant to cardio-metabolic risk factors. The computation and delivery of a comprehensive Wellness Index enables individuals to estimate and track over time their health status and their cardio-metabolic risk. Finally, the Wize Mirror offers personalised guidance towards the achievement of a correct lifestyle, via tailored coaching messages.

The Wize Mirror is designed to meet a two-fold objective: stimulating *initial adoption and utilisation*, by providing a pleasant user experience; and supporting *long-term engagement*, by helping people to establish new positive habits. To this aim, the main features of the Wize Mirror are: the provision of day-by-day monitoring in an unobtrusive way; the automatic assessment of physiological conditions via advanced data processing algorithms; and the promotion of sustained behaviour change towards long-term wellness objectives. These functionalities are developed by taking into account theories belonging to different disciplines (psychology, motivation and communication science, social marketing, behavioural theories and economics).

1. The Wize Mirror at a glance

The inspiring idea behind the Wize Mirror is that the face is the preeminent channel of communication among humans: it is a mirror of status, emotions and mood. As such it is the base of *medical semeiotics*, which reveals the healthy status of an individual through a combination of physical face signs (e.g., skin colour, subcutaneous fat), and facial expressions. Dating back as far as Aristotle, medical semeiotics is still used today by medical doctors. The Wize Mirror moves medical semeiotics into the digital realm: it translates the semeiotic code of the face into cardio-metabolic risk-related computational descriptors and measures automatically extracted from videos, images, and 3D scans of the face of people standing in front of the mirror.

The Wize Mirror is a multisensory platform which offers (Fig. 1):

- an *advanced sensing framework* for acquiring physiological data over time: the Wize Mirror seamlessly integrates contactless sensors (3D optical sensors, multispectral cameras, gas detection sensors) which collect heterogeneous data from individuals standing in front of the mirror (Section 3);
- a *multimodal data processing module*, with dedicated algorithms which extract a number of morphometric, colorimetric, and compositional descriptors correlated with cardio-metabolic risk. These descriptors define a Virtual Individual Model (Section 4);
- a *data fusion and synthesis module*, which derives a composite Wellness Index (WI) out of the huge amount of data computed. The WI is an index of the health status of an individual, to be traced over time and reported in a health diary, thus enabling users to relate their lifestyle to their wellbeing (Section 5);
- a *profiling module*, which identifies specific users' clinical history, attitudes, habits, and context, so as to tailor the system and ensure long-lasting engagement (Section 6);
- a *personalised user guidance module*, which acts as a kind of health navigator to support users in the achievement and maintenance of a correct life-style (Section 7).

The development of the Wize Mirror raises significant scientific and technological challenges. After a brief review of the state-of-the-art in Section 2, Sections 3–7 give details on

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