SmiWork: An Interactive Smart Mirror Platform for Workplace Health Promotion

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***Abstract*—This paper presents the design and implementation of a multi-user smart mirror system conceived to promote wellness and healthier lifestyles in the work environment through persuasive strategies. By means of a RFID reader, the interactive mirror recognises different users through their personal corporate ID card, which allows them to have access to their personalised user-interface. The smart mirror provides workplace's indoor environmental conditions (thermal, humidity and light), personal physical exercise data obtained from wearable devices and general purpose information (e.g. weather and daily news). Additionally, motivational advice related to physical performance is supplied through request by applying speech-based recognition techniques. End-users can also inquire the mirror about their ranking position in a fair-daily competition that gives social recognition to the most-active-user. The implemented mirror has been evaluated in a one-week study conducted in the wild in the workplace premises. The quantitative data gathered throughout the study, as well as the qualitative users' feedback obtained in a post-trial focus group, provided promising findings for the acceptance and convenience of such a persuasive device in the work environment. Furthermore, valuable design-insights were obtained for future iterations of the smart mirror that encourages workers towards healthier lifestyles.**

I. Introduction

Corporate culture is one of the central variables in our life. An average employed adult spends much of his day working [1]. As a matter of fact, workplace plays a paramount role on individual's health having a direct influence in the physical, mental and social well-being. Irregular or prolonged sitting habits and inappropriate indoor environmental conditions in work environment are associated to workers' decreasement on comfort and health [2], [3]. Aiming to bring about healthier environments and promoting lifestyle changes, the World Health Organization (WHO) established the workplace as one priority setting for health promotion into the 21^{st} century [4]. Under this context, workplace can be seen as an ideal setting to support the promotion of health for a large audience and to influence workers towards a healthier lifestyle.

Due to the relevance provided by the WHO to this issue, researchers have been studying how technology can support behavioural changes in workplaces and whether computerised persuasion can help leading healthier lifestyles [5], [6]. This challenge becomes bigger when considering office environments where the nature of the work lead to sedentary lifestyles. While existing technologies such as web pages or mobile applications are usually employed for this purpose, one of the main challenges is to provide innovative and effective tools to promote healthier lifestyles in a more natural way.

Smart mirrors arise from the transformation of a conventional mirror into an interactive information display element with special interaction capabilities. The mirror surface is an appropriate example of a natural interface because it takes part in our everyday life. Therefore, visual feedback interaction can be obtained non-intrusively through this object. In this sense, maintaining its initial functionality, the surface of the mirror is converted into a natural interface used for the visualization of information. The potential of this enhanced visualization tool for applying persuasive strategies resides in the premise that, by simply observing our reflection, a smart mirror can be seen as the main resource for encouraging behavioural changes with minimal effort for the user.

A deep review on the literature related to smart mirrors revealed that, despite it usage for smart home environment is widespread and its raided advantages to health promotion are well validated, little or no research has brought together health promotion and workplace environment. Therefore, the main goal of our study is to first design and then evaluate whether this device could be suitable for promoting a more active life fostering a healthier and more productive office work environment.

II. Related Work

Several efforts have been made pursuing the objective of adding special capabilities to mirrors, both commercial and research-based approaches. In this paper, the background provided just focuses on the latter ones.

Early ideas to create a smart mirror consisted in real time recorded images shown through a screen [7] or a projector [8] to emulate the mirror metaphor. In 2004, Magical Mirror [9] integrated the mirror surface usage and analysed its potential as an interactive multimedia display where users could have access to information services. Later works delved into this idea and included the smart mirror as a piece of furniture into smart environments [10], [11], [12]. In 2007, Hossain et al. [13] designed an unobtrusive interface which integrated both personalised data feeds and computing intelligence services for controlling household smart appliances.

In parallel with the mirror application within a smart home environment, in 2004 Philips Research incorporated the concept of health care developing an Intelligent Bathroom

TABLE I
SMART MIRROR COMPARATIVE

Characteristic	Implementation	Smart Home	Wellness	Other
Multiuser	Face Recognition	[13], [10], [27]	[22], [20], [19], [18]	[21]
	Id Tag/Other	[10], [12]	[23]	
Services	Health Monitoring	[14]	[23], [20], [15], [18], [22], [17], [15]	[21]
	Emotion Recognition	[27]	[20], [19]	
	Personal Information	[13], [21], [12], [27], [9], [10]	[20], [19]	
	Multimedia	[13], [21], [27], [9], [10], [12]		
Interaction	Voice	[13], [27], [9]	[23]	
	Touch-Gestures	[14], [12]	[23]	[26], [25]

[14] that featured an interactive mirror to support users in their daily activities. One year later, Accenture's Intelligent Home Services Initiative went one step further and presented The Persuasive Mirror [15], the first smart mirror aiming to encourage healthier lifestyles by showing the consequences of our behaviour. Its premise was that the visual stimuli of the users' self-reflection on the mirror, being provided together with personalised information, provoked a greater users' engagement [16]. Based on this idea, different scholars envisaged new designs of smart mirrors for activity tracking [17], health progress monitoring [18], emotion recognition through facial expression analysis [19], [20] and elderly care [21]. In 2016, last advances in this field included Wize Mirror [22] and Fit Mirror [23]. The former proposal was intended for health condition prevention by means of self-monitoring carried out by a complex multisensory system. The latter dealt with inferring future fitness adherence through tailored exercise, guidance and interactive games.

Smart mirrors have also been evaluated in other environments beyond households. One example is the effect of smart mirrors on customers decision support system at shops [24], [25]. Mirracle [26] is a set up example of an educational mirror conceived to be placed at schools for anatomy teaching using augmented rendering.

From the very beginning of the conception of the smart mirrors, one of the main challenges was to provide built-in user customization capabilities. Fujinami et al. [12] discussed different strategies for being easily identified in front of the mirror: face recognition, biometrical information treatment, tag identification and the state-of-use of everyday artefacts. Among these strategies, face recognition [13], [10], [27], [22], [20], [19], [18], [21] stands out as the most implemented one, while other researches lean towards the rest of the alternatives [10], [12], [23].

Either multiuser or not, the performed deep review on the literature reveals a wide range of smart mirrors' approaches and technologies. To simplify its classification, Table I summarises the main characteristics of the mentioned smart mirrors and categorises them in terms of application field (smart home, wellness and other) and implemented technologies. The mirror which is proposed in this paper implements elements from the three main categories of the table and combines the wellness application field with an area that has still attracted little attention, the workplace environment.

III. DESIGN AND IMPLEMENTATION

The proposed smart mirror implementation takes advantage of the advances in the field of system on chip (SOC) based boards using a Raspberry Pi version 3[1]. Raspberry Pi is a low cost single board minicomputer that encloses many of the main components of a complete computer, being capable of running the Linux operative system at a low-power consumption level. Thanks to its affordability, its open hardware vision and its potential, Raspberry Pi is more up-to-date than ever for the design of smart devices, and its supporting community of contributors is one of the main reasons for this growing popularity.

In terms of software, the starting point of the presented project is the MagicMirror platform conceived by Michael Teew[2]. It is an open source initiative for creating customised smart mirrors specially designed for the Raspberry Pi board. The main feature of the MagicMirror platform is its modularity which simplifies the built of personal solutions allowing creators to incorporate new functionalities through programming independent modules to be integrated in the project core. This core is based on Electron, a framework for the creation of web or desktop applications using JavaScript, HTML and CSS that runs through Node.js.

Using the provided tools several modules have been designed and programmed to fit in the desired concept of health promotion in workplace, focusing specifically on office environments. This concept involves: firstly, a multiuser system to allow every worker to have access to their personal services and track their daily activity while displaying general information. Secondly, a Bluetooth service to synchronise with the workers' activity tracking wearable devices and measure their physical activity. Thirdly, an interactive voice-controlled interface leveraged on the surface of the mirror, providing interactive capabilities. Furthermore, regarding the persuasive approach of the health promotion through encouraging workers

[1] https://www.raspberrypi.org/
[2] https://magicmirror.builders/

Fig. 1. The smart mirror set up within the workplace premises.

to healthier lifestyles, additional services have been added: 1) Personalisation; 2) Triggering of persuasive cues (following the theories of suggestion, praisal and reminders [28]); and 3) Applying gamification techniques with persuasive theories behind (i.e. self-monitoring, social comparison and recognition). The full code of the created modules can be consulted in the SmiWork project repository[3]. The details of the main implemented features are explained below.

A. Multiuser

The main interface of the mirror is oriented towards the presence of different user profiles, so that the information displayed for each of them is personalised. These profiles are managed through a module that incorporates corporate ID card identification by means of a RFID reader. When no one is logged into the system, the mirror surface shows a predefined interface where general information such as time, calendar, current weather or news feed is shown.

B. Activity tracking

Since office work involves prolonged sitting habits, encouraging workers to be more active is one of the biggest concerns to promote health in workspace [3]. Thus, one of the main features implemented in the mirror is the self-monitoring module. The main purpose of this module is to collect data about the daily activity of every worker through a smart wristband (Mi Band version 1 from the manufacturer Xiaomi[4]). Data collection is made directly from the smartband using Bluetooth and none other external application or service is used to get this information. Its operational flow is as follows: when the user logs in and gets access to his personal profile, the mirror search the user's smartband. Once it is found, the smart mirror synchronises with the smart gadget, reads the information recorded and displays it on screen. In our case, showing steps, distance and the covered percentage of worker's personal goal in order to let the user know how much activity performed that day.

C. Persuasive approach

Most of the implemented features were designed considering its persuasive potential [28]. The activity tracking feature itself is an example of applying self-monitoring persuasive theory, by showing the current status of the daily steps and distance. Besides, tunnelling persuasive theory was implemented by means of allowing the user to compare its daily physical activity to a previously pre-defined objective (10K steps) and showing the progress bar of its daily performance.

Other specifically implemented feature, call *Advice*, provides positive or negative reinforcement depending on user's performance, triggering persuasive cues. Due to this feature, the mirror shows tips, encouraging messages or even warnings about the consequences of a sedentary life (cause and effect) and users associate the mirror response to their performance as an incentive to adopt a more active behaviour. While this functionality can be seen as an individual self-monitoring feedback tool, the *Ranking* feature is designed to incentivise the physical activity from a social recognition point of view, comparing users' daily performance level and showing on a leaderboard the most active ones. Employing a game-based approach, or gamification, the desired consequence of this technique is an improvement of the motivation and engagement to the activity tracking functionality.

D. Environmental condition measurements

The presented smart mirror has been designed considering the importance of indoor environmental quality in workers' wellness [2]. With this premise in mind, additional functionalities have been added to measure and display some of the parameters that affect occupants' overall comfort. Several sensors, deployed around the smart mirror location, are the ones in charge of collecting the indoor environmental conditions related to temperature, humidity and light level. The obtained information is updated regularly and displayed in the main interface of the mirror.

E. Voice Control

Speech is the selected method for interacting with the mirror and get access to specific features. It has been enabled through Snowboy keyword detection engine[5], which is the service that supports the Amazon's Alexa[6] distribution for Raspberry. This engine is based on pre-trained vocal models of words (e.g. Alexa, Siri, OK Google) and its detection goes through listening to the input audio and triggering specific actions when a cue is detected. For the presented mirror we had to train some models for Spanish language. The activation word we selected was *Espejo*, the Spanish word for "Mirror". Each time this specific cue was detected, the user had certain time to say a command depending of the desired

[3]https://www.github.com/OihaneGomez/SmiWork

[4]http://www.mi.com/en/miband/

[5]https://snowboy.kitt.ai/

[6]https://developer.amazon.com/alexa-voice-service

functionality (the list of available commands is displayed after the *Espejo* recognition for users to facilitate the interaction). If a command is recognised during the predefined interval, the mirror performs the corresponding action. Otherwise, the voice control engine returns to idle state waiting to be activated again.

IV. Procedure

To analyse the convenience of the inclusion and acceptance of a smart mirror in the work environment, an experimental evaluation consisting in different phases was conducted. The purpose of this evaluation was to obtain both quantitative information (the statistical usage data by each user) and qualitative information (user feedback about different dimensions with regards to the suitability of this computerised persuasive mirror in workplace). The implemented mirror was physically placed in a common/shared area of the working environment where the involved researchers work, (see Fig. 1). The study lasted one-week (5 labour days, from Wednesday to Tuesday) in which 4 participants committed to use the mirror. Besides, the rest of the workers were also allowed to interact with the mirror through the default interface and they could ask for general health advice or see leaderboard of the participants' activity performance. The usage data was automatically collected by the mirror system and the participants' opinions and insights were gathered through a questionnaire and a focus group session carried out at the end of the study.

A. Recruitment

Four volunteers, all of them members of the same research group, took part in the study. The principal premise for the recruiting was that participants must have had previous experience with activity tracking devices (either wristbands or smart watches). Participants' age ranged between 25 and 38 years and they were all males. Among the participants, two people were research technicians, one was a post-doctoral researcher and the other one was a PhD student. The selected volunteers signed a consent form in a pre-study collective session. That day, the wristbands were provided to participants and the general terms of the experiment were explained without revealing the specific purpose to avoid biases. Thus, we gave them instructions about how to use the main features of the mirror interface, explaining the login method and the interaction service but no more. It is important to remark that the first days' gathered quantitative data was not taken into account for the analysis to avoid the novelty effect. At the end of the experiment, they were granted with a gift to acknowledge their participation.

B. Qualitative data

On the one side, the questionnaire handed out to participants was specifically selected to measure the persuasive potential of the system in comparison with the susceptibility of the users to be persuaded [29]. Consisting of 15 items, the different questions loaded to three main categories or constructs, designed to measure the Susceptibility to Persuasion (SP), General Persuasive Potential of the System (GPP) and Individual Persuasive Potential of the System (IPP). A 7-point Likert scale from *completely disagree* to *completely agree* was used to rate the questionnaire items. On the other side, the focus group was oriented towards obtaining participants' insights alongside four dimensions 1) the comprehensibility of the interface, 2) the interaction, 3) the motivations that arouse during the experiment to adhere to the usage of the smart gadget and 4) the relevance and convenience of the proposed approach to be implemented in workplace.

V. Results and Analysis

The information obtained during the experiment can be categorised depending on its origin and provides useful knowledge to analyse the performance of the experiment.

A. Usage Data

Quantitative data was gathered to analyse the mirror's adherence. During the whole experiment, participants logged in an average of 5.8 times per day (Mean, -M-), being its dispersion 4.48 (Standard deviation -SD-). The average number of interactions per day was 2.68 (SD=4.46). It was calculated considering only the times a user asked for advice or checked the ranking, but not for every vocal cue the voice control engine recognised. The comparative analysis presented on the top and middle plots of Fig. 2 shows the usage tendency within the whole experimental week. These plots illustrate an usage decreasement, overall in terms of connections but also in terms of interactions, after the first two days of the experiment. Despite this decreasement, participants maintained the habit of consulting their performance at least twice a day. Related to the number of interactions, more sparse results were obtained, being remarkable the lower engagement level to this feature and the interactions made by the "default" users, i.e. the rest of the workers that were not directly recruited for the experiment. A deeper analysis of every login data (bottom scatter-plot of Fig. 2 remarks how users' number of logins tends to be grouped at some points of the working day: at the beginning of the day, after lunch and before to go back to home.

B. Questionnaires

Answers related to the 15 items questionnaire were averaged separately and grouped into their corresponding dimensions (Susceptibility to Persuasion -SP-, General Persuasive Potential of the System -GPP- and Individual Persuasive Potential of the System -IPP-) as shown in Fig. 3. The results obtained from the analysis of the first dimension reveal that participants were slightly above the average in terms of susceptibility to persuasion (M=3.68, SD=1.25). Considering the obtained data with regard to the second block, the system stands out for its general persuasive potential, being seen as a suitable persuasive tool for any user (M=5.41, SD=0.79). Finally, the last dimension measures the persuasive impact the system has on a single user and its questions are related to the users' self-experience. In this case, the results showed again and over averaged score (M=4.56, SD=1.04).

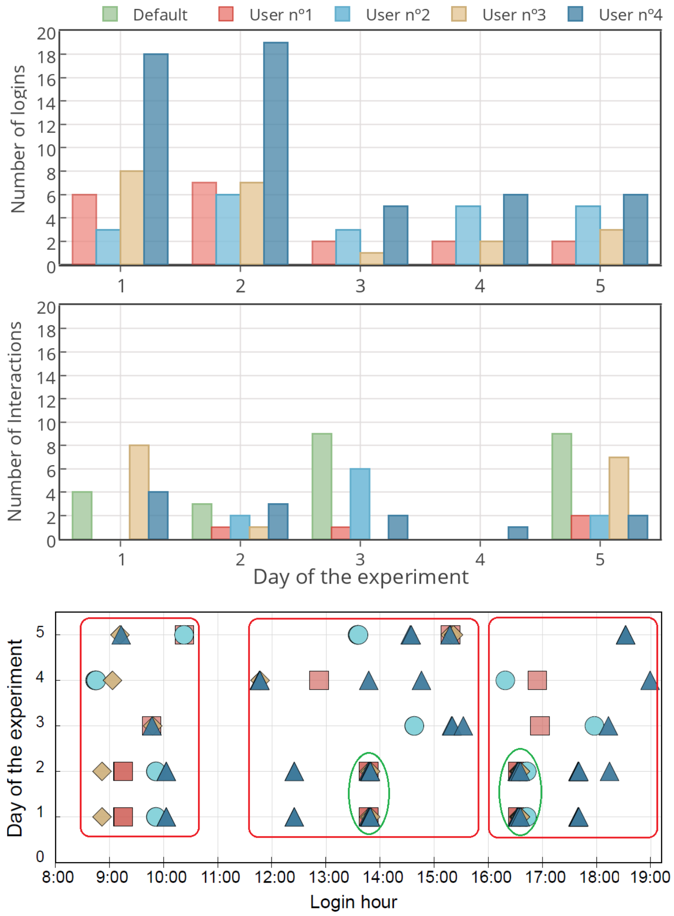

Fig. 2. Registered usage data graphs. Bar plots show the number of times every user got access to their personal profile and the interactions they made. The scatter-plot illustrates the users' access tendency to form clusters at certain hours.

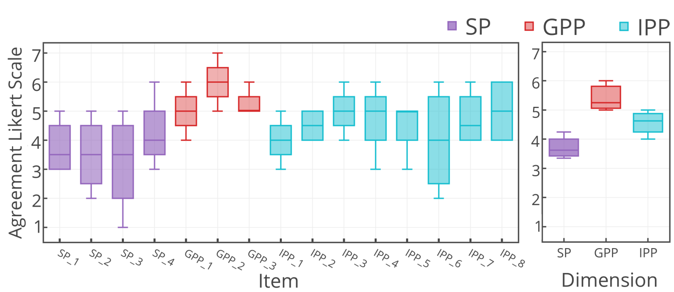

Fig. 3. The obtained results for every item of the 3 dimensions questionnaire: Susceptibility to Persuasion -SP-, General Persuasive Potential of the System -GPP- and Individual Persuasive Potential of the System -IPP-. The 7-point Likert scale goes from completely disagree to completely agree.

C. Focus Group

The organised focus group served to discuss qualitative aspects of the experience and to know the users' main concerns. The main treated topics were:

1) Usability: Users found positive the identification method, the ranking functionality and the general information displayed. On the contrary, some aspects of the interface design, as well as the voice interaction approach, suggested improvements for future iterations. Voice control was identified as a useful tool. However, the tension between the speech-based interaction and the quietness requested in the workplace was an unresolved issue to be addressed.
2) Persuasion: The comparative ranking that provided information about the participants' physical activity was considered the most successful feature. Participants were more interested than before on tracking their daily activity and they tried to stay more active to reach a better position on the leaderboard. However, persuasive cues (following the theories of suggestion, praisal and reminders) did not prove an equal engagement since its use involved voice-based interaction. Users suggested that advice should be shown automatically instead needing to inquire the mirror for them.
3) Location: Different locations to place the mirror, such as the bathroom, the lounge room or the elevator, were proposed in the focus group. Participants agreed that seeing other people interacting with the mirror worked well as an attractor to adhere to use it. In general, interviewees were favourable to place it in a location similar to the one where the experiment was conducted.
4) Privacy: When asked about what kind of information they wanted to see displayed, none of the participants chose personal information such as their email or calendar due to privacy concerns related to the previous dimension: the Location. In general, considering the deployment of the smart mirror for large audiences, participants would feel uncomfortable whether their activity data was publicly accessible.
5) The mirror concept: Participants agreed that they have never used the mirror to see their own reflection, and they considered it more as an information point like digital signages or digital kiosks. Regardless that misconception, participants remarked its advantages over a mobile app or a classical web-based app, due to the social component that the Location topic provides. One of the participants also recognised the potential of the augmented reality metaphor to interact with the mirror.

D. Discussion

The applicability of the persuasive theory of social recognition has proved potential to work as an attractor towards increasing the usage and adherence of the presented system. This is supported by the data obtained when analysing the login information where data clusters of the Fig.2 showed that at certain moments participants joined to check their performance together. Moreover, the questionnaire provides results which are in line with the quantitative data: General Persuasive Potential of the smart mirror was assessed rather high among all the participants. This finding is reaffirmed with the opinions expressed during the focus group when the participants were asked to express their motivations to use the system. Interviewers claimed that their motivations to be more active were reinforced when a colleague was observed using the mirror. Following the Ajzen's theory of planned behaviour [30], these motivations and intentions can be considered as a predictor for lasting use of the mirror throughout the time.

VI. Conclusion and Future work

In this paper we have presented the design, implementation and evaluation of an interactive system called SmiWork: A Smart MIrror devised to motivate more physical habits in the WORKplace. Both quantitative and qualitative data were gathered during the experiment to test the suitability of this approach to be deployed in work environments. The multi-user approach towards using RFID as a mean to recognise users provided an adequate interaction method for accessing to personal information. Moreover, the activity tracking feature worked appropriately as engagement element when combined with social recognition persuasive theories. In this sense, the presence of the smart mirror in a common area and the possibility to compare the users' physical performance through gamification proved to be effective for health promotion, engagement and adherence.

The analysis of the obtained knowledge provided the basis for the future work. Technically-wise, an enhancement of the mirror's reflective surface and additional interaction methods beyond speech are some of the future improvements. Research-wise, we envisage a more proactive persuasive approach to attract the users' attention towards using the mirror. The preliminary insights obtained can be used to set the right focus to boost the potential of the smart mirror device in the desired concept of health and wellness promotion in the workplace.

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