Let us Get Real! An Integrated Approach for Virtual Coaching and Real-time Activity Monitoring in Lifestyle Change Support Systems

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***Abstract*—There is a fast growing number of eHealth systems aiming at supporting a healthy lifestyle. Tailored lifestyle coaching services offer individual users access to web portals where they can communicate about a growing number of ingredients of everyday life concern: physical activity, nutrition, medication, mood, sleep. Mobile technology in combination with body worn sensors support user's awareness of their physical condition and lifestyle. Despite the large number of available lifestyle interventions and pilot trials, only very few are successfully transferred into the real health care practice. This paper presents new insights and recommendations for the design of lifestyle support systems with personalized virtual coaching based on two user studies. The first study focuses on the mobile physical activity coaching for diabetes patients and office workers. The second study summarizes the persuasive factors on attitudes of high-risk adolescents towards a virtual coach in mobile eHealth applications and social media. We present a new approach that integrates an animated digital coach in an activity monitoring lifestyle change support system.**

Keywords*-Mobile Activity Monitoring, Personalized eHealth; Persuasive Feedback, Usability; Virtual Coaching; Behavior Change; Lifestyle Interventions

I. INTRODUCTION

Recent massive media attention to the obesity epidemic worldwide and growing number of patients with chronic diseases raises the demand for encouraging physical activity and raising health awareness [1]. Next to classical web-based interventions, eHealth behavior change support systems for healthy lifestyle promotion aim to motivate patients to healthy behavior change [2] [3] [4]. Some systems become proactive and provide real time information and feedback to their users based on data gathered through various sensors and personal devices [5] [6].

Despite the large number of existing lifestyle interventions and pilot trials, only very few are successfully transferred into the real healthcare practice [7] [8]. Users often have problems to navigate through the system, they get lost or they do not find the information they are looking for [9]. Low usability and lack of transparency on the reliabilty and trustworthiness of the information are just a few examples of the major barriers for successful implementation [4] [7] [8]. There is also a lack of standardization for interoperability between various parts of the systems and a lack of connection between the feedback, the actual usage patterns and the task a user is involved in [10]. These problems are often caused by a design that does not meet the actual needs of the target users while using the system and a lack of connection with offline, daily, activities. A holistic design approach for eHealth intervention development which we use in our research has proven to contribute in overcoming these barriers [8].

This paper presents new insights and recommendations for the design of lifestyle support systems with personalized virtual coaching based on two user studies. The studies represent different perspectives on eHealth systems. The first study has a Human Computer Interaction (HCI) perspective and focuses on the use of a virtual animated character in a multi-device mobile physical activity coaching system for diabetes patients and office workers. It was performed at the Human Media Interaction group of the Computer Science Department at the University of Twente. It was carried out in the context of the EU funded Artemis project Smarcos, led by Nokia, VTT and Philips. The overall theme of this ICT project is the inter-usability of multi-device multi-sensor systems. The second study summarizes the persuasive factors and attitudes of high-risk adolescents towards virtual coach in mobile health applications and social media. This study was performed at the Center for eHealth Research and Disease Management, Psychology Health and Technology group of the Behavioral Sciences Department at the same university.

In the next section, we first highlight findings from related work on physical activity monitoring, virtual coaching and mobile eHealth applications for lifestyle support. After that, we present a new approach for a multi-device coaching system based on the outcomes of two user studies on virtual coaching for lifestyle support. The first study describes results of the user evaluation of the mobile physical activity coaching system for office workers and diabetes patients. The second study focuses on persuasive factors and attitudes of high-risk adolescents towards virtual coaching, social media and mobile apps for sexual health promotion. Summarizing the main outcomes, we then present recommendations for the design of lifestyle support systems with personalized virtual coaching. Finally, we present the main conclusions and discuss future work.

II. RELATED WORK

There have been various attempts in categorizing eHealth technology [5] [8] [11] [12] [13]. In this paper, we focus on monitoring physical activity and health related parameters (blood pressure, weight) in lifestyle interventions for preventive professional care support. A categorization is based on the type of platform that the eHealth technology is realized on: stand alone devices; integrated web-based interventions and personal mobile devices; or a combination of various devices to monitor online and offline activities of a target user. We will highlight the multi-device approach which falls into the category.

A. Physical Activity Monitoring and Coaching

Wearable health technology, such as activity sensors, is often used as a surveillance tool to objectively assess physical activity patterns [6] [14] [15]. They provide an inexpensive, accurate, and reliable objective measure of physical activity by counting the number of steps taken per day, enabling the accumulative measurement of occupational, leisure time, and household activity, along with activity required for everyday transportation. In addition to their use as a measurement tool, activity sensors are also a popular motivational tool. The ability of an individual to receive immediate feedback on their accumulated step count is an important feature of the motivational aspect of the applications using activity sensors data [15]. A comparative study suggests that the greatest increase in step counts occurs when participants are requested to wear an unsealed sensor and record their step counts real time.

Engaging patients requires user friendly interfaces and user friendly interaction with the systems. Patients often have to cope with various physiological measurements instruments (either active or passive): blood pressure, blood sugar and weight. Willingness to measure these parameters strongly depends on the complexity of the user interface of the measuring device or sensor, as well as the data transfer process [16].

Based on an extensive literature study, H. op den Akker et al. [17] identified six key areas for research to improve digital coaching for physical activity by tailoring to the individual user. Two of them are of interest here: advanced Human-Computer Interaction (HCI) and pervasive coaching. To increase perceived intelligence of a coaching system, a virtual coach offers an interesting opportunity as an interface metaphor. Bickmore et al. [2] studied the effects of interventions for multiple health behaviors using conversational agents as a coaching system. This study showed that virtual conversational agent as a coach can have a positive effect on perceived relationship of a patient with an eHealth system.

Computer tailoring and personalized eHealth offer great potential for motivating people by providing personal information and feedback [18]. Characteristics of an intervention, such as enabling personal goal setting and providing tailored feedback are thought to be among the important factors related to of use of and exposure to lifestyle support systems. Next to tailoring, personal feedback needs to be dynamic to provide new information and real time feedback on the daily activities. The user study of Consolvo et al. [14] reports that negative feedback or paternalism has a negative impact on the users.

B. Mobile eHealth and Coaching

Mobile devices providing personalized feedback to influence physical activity behavior are gaining more and more popularity [19]. There are few examples of mobile health applications (apps) specific for behavior change and physical activity support [5] [19] [20]. Despite a huge range of health-related apps on the market, there is little in depth research on user experiences and views on a wide range of features that apps can provide.

Fanning et al. [19] present extensive review on efficacy of mobile devices in the physical activity and recommendations for implementation. This study concludes that mobile technology applied in behavior change interventions is an effective tool for increasing physical activity.

User studies in mobile health research are rarely performed with young adults, though adolescents are forerunners of mobile technology. Dennison et al. [20] present the findings of a focus group study with students on the use of mobile apps to support a healthy lifestyle, the attitude of adolescents on the usefulness of various features of such apps. The results suggest that the most important factors influencing the use and uptake of mobile apps are accuracy, legitimacy, security, effort required, and immediate effects on mood. Another features that young adults valued were ability to record and track own behavior and goals, as well as the ability to receive advice and real time information. Interesting finding from this study is that context-sensing capabilities of mobile apps and social media features were perceived as unnecessary.

Consolvo et al. [14] reports a long-term user evaluation with the UbiFit system which aims at raising individual awareness on physical activity level. The results show that glanceable representations of information on personal, mobile displays can stimulate the person to do more exercises. These findings are consistent with another study [21].

C. Serious Gaming for Lifestyle Support

New forms of entertainment media such as serious gaming are used for promoting healthy lifestyle [22]. Serious gaming and interactive gaming elements embedded in eHealth technology offer great potential in innovative opportunities for engaging adolescents and other patients in interventions promoting healthy nutrition habits and physical activity changes that can contribute to obesity prevention and healthier lifestyle [22].

III. User evaluations of a mobile animated activity coaching system

As humans interact with many different devices during the day, cross media systems offer the opportunity for the activity coach to travel with the user across those devices. Depending on the needs and context of the user, coaching can thus be provided on the most suitable device (e.g., smartphone, PC, smart television) [23].

A. Digitial Coaching Architectures

A multi-device digital coaching can have a more *centralized* or a more *decentralized* architecture. The main difference is in the measure of autonomy of the mobile coaching application. The Continuous Care & Coaching Platform (C3PO), developed at Roessingh Research and Development (RRD) in the Netherlands, enables continuous remote monitoring of elderly patients and patients with chronic disorders [24]. In the C3PO platform, there is only one device with which the patients users interact, the smartphone. The care givers can view patient data that is uploaded to a server. An activity monitoring and feedback system was designed to guide patients in reaching a healthy daily activity pattern. Objective daily activity is assessed using an inertial sensor node that captures and communicates wireless. The sensor can store large amount of data and send the data over Bluetooth to a PDA (an Android based HTC Desire) where further processing and communication to the patient is handled. The users receive feedback on their smartphone at scheduled times or if their activity level calls for this. In this *decentralized* architecture the coaching rules reside on the client-side mobile. In contrast to this, in the *centralized* architecture of the Smarcos platform the coaching rules reside on the server (see Figure 1 for an overview). Based on server side stored sensor data or on fixed times, the server sends a message to the client, who can receive the message on the device of his own choice. To upload activity data the user has to connect his sensor to the internet.

In the Smarcos system, feedback is a reminder to connect the activity monitor to upload data, a motivating message when activity is less than the target or an overview of daily, weekly and monthly scores. A drawback of the Smarcos system compared to the RRD system is that feedback is not real-time. The RRD system allows immediate feedback based on recent data collected from the sensor. A call for urgent medication intake (e.g., in a diabetes I medication coach) requires real-time feedback. In the Smarcos system, scores are presented as percentages of a user set target score and in terms of kCal. The user can get these activity overviews on his mobile device app, as well as via a web portal.

B. User Evaluations: Animated Virtual Coach

User evaluations were performed throughout the development of the Smarcos coaching system [23] for physical activity support and diabetes II patients. We performed short user evaluation with diabetes patients and office workers. We focused on the graphical user interface, on the interaction and on personal feedback in particular. We looked at timing, content, modality and presentation format. We are particularly interested in the application of animated virtual humans and multi-modal natural dialog as a means for interaction between the user and the digital coach. At the Human Media Interaction group we developed mobile technology for responsive animated Embodied Conversational Agents (ECAs) [26] for the presentation of feedback on a mobile app. The system can produce ECA behaviors (eye blink, eye gaze, head movements, lip sync with natural speech and facial expressions) specified in the Behavior Markup Language (BML) [27]. In the centralized Smarcos system the server sends a feedback message to a client containing a BML specification. The BML contains the text to be pronounced by the ECA as well as the non-verbal embodiments.

The mobile animated virtual coach was used in several short user experiments with the Smarcos architecture, as well as with the decentralized coaching platform developed at Roessing Research and Development [23].

In a ‘long-term’ user evaluation with the Smarcos system office workers (forty-one completed the evaluation, aged 21-57 years) were randomly assigned to one of three groups: one group (N=19) received feedback as text (TXT), a second group (N=15) received feedback by an animated agent (ECA). A third control group (N=9) did not receive feedback message on the smart phone. They could only get feedback via the web portal. Overview of activity is shown graphically in both conditions. Interviews and questionnaires were used at the start, halfway and at the end of the six week period. After a calibration week to measure their regular daily activity level users could set their target activity level themselves. This level is presented as a reference for the actual daily activity.

Results of a six weeks user evaluation with the physical activity coaching system show that Physical Activity Level (PAL) values do not differ between the ECA and TXT condition. Thus feedback by means of an ECA has no added value over feedback by means of a text message if we look at the target objective. The control group that did not receive feedback and no reminders to upload their sensor data performed worse compared to both ECA and TXT group. In particular, in the control group the mean of the PAL values dropped from week 4 onwards. We used a Mann-Whitney U test to compare the results between the different groups. At the end of week 6 the PAL level of the ECA group wa significantly less than the mean for the TXT group $((Mdn = 1,61), U = 36,00, p = 0,014, r = -0,460)$. The number of uploads of PAL data in the control group was significantly less than in the TXT group during all six weeks $((Mdn = 3,00), U = 51,00, p = 0,045, r = 0,378)$.

Interviews and questionnaires reveal that on smartphones users prefer glanceable presentation of feedback messages. Reading the short text message is faster than listening to the spoken message. Smart phones are for quick access and glanceable presentation of feedback fits the message and the use context. In line with the conclusions of Lisetti et al. [28], we believe that the opportunities offered by the technology of animated conversational characters are exploited fully in multi-modal spoken personalised emphatic dialogs with the user. The user evaluations reported by Lisetti et al. had a similar objective as ours but the research methods differ in a number of ways. The most important is that Lisetti uses a lab test; therefore, we had a real-life evaluation. A second important difference is that our ECA platform is based on the BML framework and runs on mobile platforms. This offers new opportunities for coaching systems in clinical applications.

A cross media or multi-device coaching system can support the execution of an intervention program in which a team of human and virtual coaches work towards a negotiated goal, or to sustain a certain lifestyle. Such a blended format combining virtual coaching with real-world coaching is a novelty in HCI design.

IV. User Evaluations: Persuasive Design Factors for eHealth and Social Media Apps

Sexual health is a specific sensitive subject in many cultures and there is little research on the effects of prevention-focused interventions in this domain. The exploratory user study aimed at identifying the design features interventions have to possess to facilitate qualitatively well-designed and tailored eHealth interventions in the future and to evaluate currently available ones. We investigated which design factors are important using

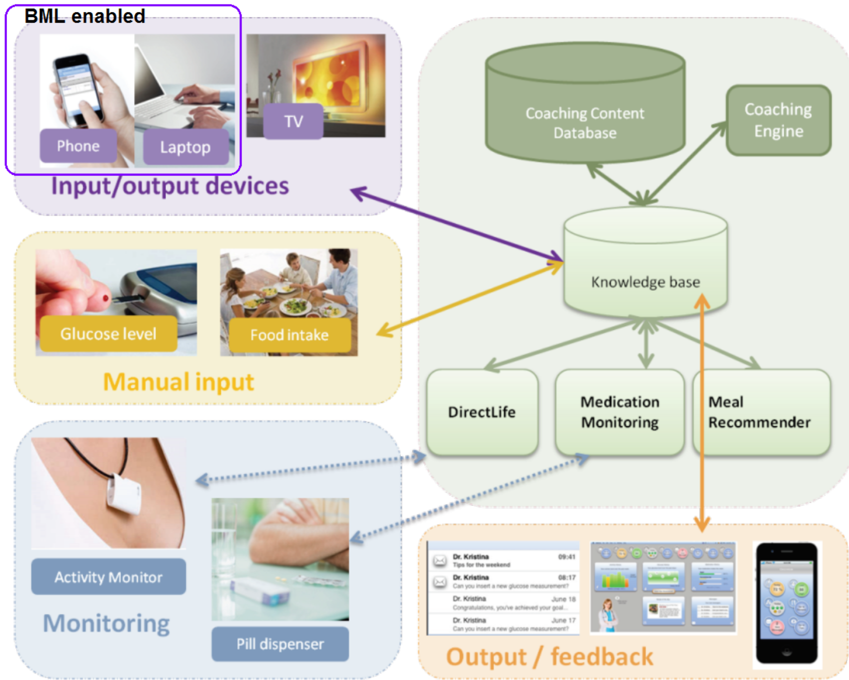

Figure 1: Overview of the multi-sensor multi-device digital coaching system developed in the Smarcos project [25].

focus group discussions with high-risk adolescents. The user study focused on social media, serious games, mobile applications and the use of personal virtual coaching for lifestyle support. Primary research question was which persuasive design factors influence the use and adoption of various eHealth interventions in public sexual health services.

In total, 37 young adults with low socio-economical and various ethnical backgrounds (51, 4% male and 48,6% female; age 12 - 24 years, M=17,4 SD=3,1) participated in four focus group discussions. Participants are considered as having ethnic origin in case if at least one parent comes from abroad. Participants explored and gave feedback on a number of existing and new social media applications and modern media applications in a focus group setting. All sessions were audio recorded with participants permission.

Participants were also asked to express their opinion about the three new concepts for new media applications integrated in modern social media, namely, (i) a serious game embedded in the existing social network, e.g., Facebook, (ii) a mobile application functionality embedded in Facebook, and (iii) a personal virtual coach embedded in either a social network, a website or a mobile application. Each concept represented certain persuasive factors which were discussed using clear visual examples without naming the exact factor.

In the last part, adolescents shared their own ideas and tips about promoting public sexual health services and healthy lifestyle via eHealth applications and social media. The script, the power point slides and the duration of various parts of the focus group session were first tested during a pilot session and adjusted based on the outcome. An assistant took notes and answered questions about the group assignments.

During the data analysis, audio files were fully transcribed, analyzed, coded and categorized. The social support elements have been coded according to the Persuasive System Design model [29]. An analysis of the influence of persuasive factors on the response of adolescents towards various types of presented media was done.

A. *Result of the Focus Group Study*

The results of the focus group study showed that adolescents have positive attitude towards the use of a personal virtual coach for health promotion, as long as they perceive there is a real human behind the virtual character. Several important design factors were identified during the data analysis. Anonymity was found as the most important factor, which has important implications for the use of social networks for sexual well-being enhancement. Social media networks lack privacy and therefore eHealth applications, for example on Facebook, are not a recommended media for enhancing sexual well-being of high-risk adolescents. Instead, social networks can be used to increase the familiarity of the target group with the existing interventions. The next factor, level of interactivity was identified as indispensable. Serious games and mobile applications are expected to have a high level of interactivity to better engage users and thus increase uptake of lifestyle interventions. The type of platform the eHealth technology is realized on was another essential factor. Personal mobile devices, and smart phones in particular, were most preferred due the high level of privacy and familiar user experience. In addition to the factors mentioned above, the reliability of the information source was clearly an important issue across all media types. Participants stated the importance of the clear visibility of the information source, as well as the logo or the name of the health organization behind the intervention. Another factor, namely, support for visual aids, was also identified

 ISBN: 978-1-61208-327-8

across all types of applications. Specific to adolescents with low soci-economical background, lifestyle interventions have to be more visually aided. The language use in the content has to be simple, low threshold and preferably in several languages to reach various ethnic groups. Applying these factors in the design of eHealth technologies should increase their uptake and usefulness for enhancing sexual well-being of high-risk adolescents and contribute to healthier lifestyle.

V. Lessons Learned: Personal Coaching and Lifestyle Support

What have we learned from studies about the effects of a virtual coach in lifestyle coaching systems? In general, user studies showed positive attitude towards the use of a virtual coach for lifestyle change support. Users prefer to be in control of how, when and on what device they want to receive personal feedback from a virtual coach. In addition, we learned that users want to monitor their history and progress: what they have done and what they should do next. They expect a connection between the goal-setting features for behavioral change and the personal coach to support them.

Motivation is an important factor when it comes to the willingness to use a particular lifestyle coaching system. It makes a difference if an eHealth intervention is supported by a real human healthcare professional. Effective coaching and tailored feedback in terms of its timing, content and interaction design are crucial elements in affecting behavioral change. The next generation of the lifestyle coaching systems will be able to predict the optimal timing for providing feedback by analyzing previously given feedback messages. A personal target has to be challenging and reachable, step by step, within a set period of time.

Next lesson is the need to provide personalized (tailored) feedback: show progress towards target, adjust target, motivate, suggest actions, provide real time information. Facilitating navigation through information that user needs is also found important, for example by offering a user to search information by alternative interaction modalities such as speech input. However, the coach should not talk to the user when the head phone is unplugged. Therefore, a context-sensitive smart sensors technology is needed to enable this feature.

Online coaching also needs to be better integrated with offline feedback to stimulate the participation and commitment of the user to a lifestyle intervention [30]. Combining real-time usage behavior data with personalized virtual coaching and timely persuasive feedback can contribute to higher engagement and better uptake of lifestyle change support system by patients as well as healthcare professionals.

VI. Conclusion and Future Work

Applying user-centered design techniques can significantly improve the appeal of the user interface and thus the engagement with personal lifestyle coaching system [31]. Next to the ease-of-use, visual appeal and clear presentation, the user experience has to be enjoyable and rewarding. Active engagement of the user in interaction with lifestyle intervention is crucial to ensure prolonged use of an intervention.

There is a need for guidelines and standardization for eHealth technology in general [10], as well as for the lifestyle interventions, in particular. In addition, the multi-device architecture is necessary to enable easy exchange of monitoring data between web-based and private mobile parts of lifestyle support systems. This paper makes two contributions: (1) new insights into the existing lifestyle interventions with virtual coaching, their limitations and recommendations for improvements (lack of unanimity in interface and interaction, etc.) and (2) integrated approach, by considering a multi-device eHealth system with motivational design features (such as timely feedback) which increases the involvement of patients as well as healthcare professionals.

To conclude, lifestyle behavior support systems need to be be evaluated throughout all stages of the eHealth technology development cycle. Furthermore, it is also essential to evaluate the effects of eHealth interventions that have already been disseminated, using multidisciplinary approach and by independent evaluators.

A. *Future Challenges in Evaluating eHealth Systems*

One of the main future challenges in eHealth technology [10] is developing a mixed methods approach and standards for evaluating the effects of eHealth from a user perspective [5] [8]. Validated instruments for user evaluations are needed to measure the effects of personalized eHealth interventions, such as changes in lifestyle or other behavior change [32]. The field of eHealth technology and telemedicine can benefit from adopting design and evaluation methods from the field of HCI. HCI evaluation methods are well suited for the short-term user evaluation to measure the effects of intervention before the long-term implementation. Naturally, HCI evaluation methods need to be adjusted to the specific goal of the eHealth technology and multi-device lifestyle support systems in particular [31]. In return, HCI field can benefit from the active logging methods and eHealth techniques for analyzing usage behavior patterns for better tailoring of personalized feedback [9] [10] [33].

VII. Acknowledgments

We thank all participants of the focus groups and other user studies, Municipal Health Services and social workers. Special thanks are due to Irina Lehmann and Cristel Boom for assistance in recruitment and data analysis. Part of the work presented is funded by the EU, within the framework of the ARTEMIS JU SP8 SMARCOS project 100249. Focus group study is a part of Sense eHealth project funded by the Ministry of Health, Welfare and Sport (VWS) and is carried out in collaboration with the Dutch National Institute for Public Health and Environment (RIVM).

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 ISBN: 978-1-61208-327-8