Promoting a Healthy Lifestyle: Towards an Improved Personalized Feedback Approach

R. Achterkamp, M. Cabrita, H. op den Akker, H. J. Hermens, M. M. R. Vollenbroek-Hutten

***Abstract*—Technology supported services for achieving a healthy lifestyle have shown their short term effects and are receiving increasing interest from the research community. However, long term adherence to these services is poor. This paper describes research-in-progress regarding the implementation of automated goal-setting and tailored feedback messages into one such technology supported service, which aims to improve the user's physical activity pattern. Tailored feedback messages for several personas were set up based on theories from behavioral science and categorized by experts during an expert workshop. Results indicate reasonable agreement on the matching of motivational messages to four personas. Additional expert input is discussed descriptively. Future research will focus on examining the effectiveness of the new version of the service under investigation.**

***Index Terms*—Accelerometers, Behavioral science, Physical activity, Telemedicine.**

I. Introduction

PEOPLE live an increasingly sedentary lifestyle, resulting in a decrease in health and posing a risk for various diseases (e.g. [1]). On the other hand, a physically *active* lifestyle has significant positive effects on prevention of chronic diseases, such as cardiovascular disease, diabetes and cancer. Also, a sufficient level of physical activity has positive effects on mental health condition through reduced perceived stress and lower levels of burnout, depression and anxiety [2]. Therefore, a physically active lifestyle may lead to less hospitalization, higher life expectancy and improved well-being in general. Currently, many applications that support people in achieving an active lifestyle are available. One such example is the Ambulant Activity Feedback System (AAFS) [3]. The AAFS measures the activity of users during everyday life using an accelerometer-based sensor. Data is sent from the sensor to a smartphone, which displays the information to its user. The user's cumulative activity is plotted in a graph that also shows a goal line, based on the average activity of a group of healthy control subjects. The system is able to coach the user. Based on the percentage of deviation from the goal line, the system provides motivational cues on whether the user needs to become more active (e.g. take a short walk) or take a break, in order to achieve a balanced, daily activity goal. Previous research indicated the potential of this system [3]. However, it also showed that the adherence to the system dropped substantially after a few weeks. It is expected that this lack of adherence to the system and decrease of effectiveness can be overcome by adding 1) context aware goal setting and 2) personalization of information, i.e. tailoring [4].

This publication was supported by the Dutch national program COMMIT (project P7 SWELL).

R. Achterkamp is with Roessingh Research and Development, Enschede, OV 7522AH, The Netherlands and the Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, Enschede, OV 7522NB, The Netherlands (e-mail: r.achterkamp@rrd.nl).

M. Cabrita is with Roessingh Research and Development and with the Physics Department, Faculty of Science and Technology, Universidade Nova de Lisboa, Lisbon, Portugal.

H. op den Akker, H. J. Hermens and M. M. R. Vollenbroek-Hutten are with Roessingh Research and Development and the Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente.

II. Background

A. Context aware goal setting

When Locke and Latham first proposed the Goal-setting Theory [5], it mainly focused on questions regarding motivation in work settings. However, its promising results made it one of the most commonly used theories to promote a healthy lifestyle. According to the Goal-Setting Theory, people are more likely to change behavior the higher the specificity and (achievable) difficulty of a goal. However, one should always bear in mind personal characteristics of the subject, such as goal importance, self-efficacy and feedback. Research regarding physical activity interventions shows that combining goal-setting and persuasive technologies can significantly improve the results of interventions [6]. When setting goals, baseline level of physical activity of the user should be assessed first, based on which a personal goal can then be set. Setting a goal based on the average activity of a group of healthy controls will in many cases lead to users not reaching their goal. Furthermore, considering the applicability of technology supported services to various domains, patients, for example, would struggle to keep up, possibly never reach their goal and simply give up. Therefore, we recommend to automatically adjust the height of a goal and set it slightly higher than the personal baseline.

Another important aspect, next to height of the goal, is the physical activity pattern throughout the day. Research into the physical activity pattern of chronic low back pain patients [7] and patients suffering from chronic fatigue [8] shows that these patients are unable to balance their physical activity pattern throughout the day. Our solution is to incorporate context aware automated goal setting; enabling the technology supported service to automatically detect imbalances in the user's physical activity pattern, set goals and continuously keep these goals up to date.

B. Tailored feedback messages

Feedback based on subjective measurements can have an equally large effect as feedback based on objective measurements. Research shows that interventions that used tailoring on *attitudes*, *self-efficacy*, *stage of change*, *social support* or *processes of change* showed significantly larger effect sizes than interventions that did not tailor on these constructs [9]. Also, guidelines for designing effective physical activity interventions strongly recommend tailoring feedback [10].

Given the above, providing real-time motivational cues that are based on constructs from behavioral science and the user's current level of physical activity seems a promising solution to the lack of long term adherence to e-health services. Indeed, s*elf-efficacy* and s*tage of change* are already identified as two important constructs from behavioral science [11]; it is recommended that users receive feedback messages based on their individual scores on these variables. Achterkamp et al. [11] identified eight typical users – so called personas – usable for technology supported services that are aimed at improving physical activity. Given a subject's score on a self-efficacy questionnaire, stage of change questionnaire and the user's own baseline level of physical activity, subjects are identified as one of these eight personas. Subsequently, each persona is recommended one of six feedback strategies, which serve as literature-based guidelines to set up tailored feedback messages.

III. CONTEXT AWARE GOAL SETTING

Whereas in previous versions of the system, the goal line was fixed throughout the intervention period; we now describe the smart reference module that automatically generates personalized and self-adjusting goal lines for individual users of the system.

A. Baseline Period

The first seven days after users have received the system are considered the baseline period. During this period the system defines 1) a baseline for each day of the week and 2) the best feedback strategy to adopt for the specific user based on the user's daily physical activity pattern and results from questionnaires assessing self-efficacy [12] and stage of change [13] (the use of these feedback strategies is explained in Section IV). We intend to make a continuously adapting system that follows not only the user's routine, but also their progress through time regarding the psychological constructs. This information can be accessed by healthcare professionals through the web portal

B. Intervention period

During the intervention period, users receive time-related motivational cues. The content of these messages depends on 1) the feedback strategy that is appropriate for this user and 2) the deviation of the user's physical activity level from the goal line. Each feedback strategy has three types of messages: encouraging (meaning to encourage users to increase their activity), neutral (letting the user know that they are performing well) and discouraging (telling the users to slow down their physical activity in order to achieve a good balance over the course of a day) [7].

Taking Monday as an example, the data acquired during the day is averaged over short time intervals. The system then computes the Linear Weighted Moving Average (LWMA) of the data from all the previous Mondays with the new data, as in (1).

$$LWMA(newEndPoint, N)_i = \frac{\sum_{j=1}^{N} newEndPoint_{i-N+j} \times (i-N+j)}{\sum_{j=1}^{N} j} \qquad (1)$$

In addition, the Activity Coach tracks the percentage of total activity that the user should achieve at different times of the day. As an example, a user should accomplish 40% and 70% of the total daily activity at 12.00 and at 17.00 respectively. These points are dynamic and can be changed by the health care professional on the web portal or adjusted according to the user's agenda or other contextual factors.

The new goal line is defined in two different steps: first the end point will correspond to a slight increment of the weighted end point of all previous Mondays. Second, based on this end point, the goal line is defined by calculating an optimal distribution between what the user has accomplished on average and the goals previously defined. The ideal distribution is the one that would give a challenging but achievable goal all throughout the day in line with Goal Setting Theory.

Moreover, the user's physical activity pattern is classified as either balanced or imbalanced according to a minute by minute calculation of deviation from the goal line.

Additionally the LWMA of different periods of interest (e.g. morning-afternoon-evening) is calculated and stored in the system. This information can be considered as additional feedback to inform users about their daily activity pattern.

C. Subjective measurements

As users will move through various stages of change and levels of self-efficacy while using the Activity Coach, they will be prompted with a self-efficacy questionnaire and stage of change questionnaire every four weeks. Which feedback strategy to apply accordingly is automatically decided by the system by combining these two variables with the classification of the user's physical activity pattern (i.e. how often they achieve their target goals, and how often they show a balanced versus imbalanced activity pattern).

D. Future work

In order to further personalize the goal pattern (particularly in terms of balance) we will incorporate a user agenda into the system. By asking users to fill in their weekly schedule (sleep, travel, work, and leisure time) we can use this information to determine appropriate times for which we can increase the expected amount of activity performed, effectively raising the goal line at those moments. For example, for typical office workers, such appropriate times are most likely to occur after working hours. Recent developments in automated, semantic location tracking can replace the process of querying for explicit user schedules by automatically determining working hours, travel time and time spent at home. Weather information and nutritional planning are other functionalities to add in the future.

IV. TAILORED FEEDBACK MESSAGES

Tailored feedback messages were set up based on personas and feedback strategies identified in earlier research [11]. See Table I and Table II.

To validate the categorization of messages to the feedback strategies, four psychologists were invited to match the feedback messages to the corresponding feedback strategy or strategies. The focus was on feedback strategies that aimed at personas with low self-efficacy. Participants individually categorized every message to one or more feedback strategies. Next, all messages were discussed with the group to identify flaws and allowing participants to give feedback. Results were analyzed by calculating Cohen's Kappa. Kappa ranged from .373 to .692 and averaged .483 (Table III).

TABLE I
EXAMPLES OF FEEDBACK MESSAGES

1.	"Earlier you indicated that you do not have the intention to adjust your level of physical activity. Are you satisfied with your current level of physical activity?"
2.	"You're doing very well this morning, but keep in mind to save some energy for the evening."
3.	"You indicated that you wanted to become more physically active; very good! Try to plan a daily walk for the next week."

TABLE II
EIGHT PERSONAS

	Intention to change (contemplation, preparation and action)		**No intention to change (precontemplation and maintenance)**	
	Level of activity		**Level of activity**	
	Improper	**Proper**	**Improper**	**Proper**
Self-efficacy Low	Persona1	Persona2	Persona5	Persona6
Self-efficacy Average-high	Persona3	Persona4	Persona7	Persona8

TABLE III
COHEN'S KAPPA INTER-RATER RELIABILITY

	Expert 1	**Expert 2**	**Expert 3**	**Expert 4**
Expert 1	-	.373	.459	.417
Expert 2	.373	-	.439	.519
Expert 3	.459	.439	-	.692
Expert 4	.417	.519	.692	-

V. CONCLUSIONS

Clinical experimental evaluation of the Activity Coach, implementing the smart reference module (Section III) and the tailored feedback messages (Section IV) is planned for the second half of 2013. The tailored feedback messages have been implemented into the system and users are appropriately categorized to the feedback strategy that is best suited for the individual user. Before clinical validations take place, we aim to evaluate the goal setting algorithms through simulation using physical activity data from real users. These users are under supervision of a physiotherapist who will judge their physical activity progress and balance from day to day. This gives us a gold standard of target activity and activity balance, enabling us to fine tune our algorithms to match the expert's opinion. As these users will be wearing the Activity Coach for a period of time, we are also able to observe the self-adjusting behavior of our algorithm.

The experts showed a fair to moderate agreement on how to categorize the feedback messages. Partially, these low values can be explained by the subjective nature of the categorization. Although the experts received detailed information about the personas and feedback strategies, the feedback strategies could still be interpreted differently by the various experts. Another workshop will be organized to categorize messages related to the feedback strategies that were not discussed.

Future directions of research regarding technology supported services should focus on tackling common problems regarding adherence and focus on incorporation of more context awareness and constructs from behavioral science.

REFERENCES

[1] T. Y. Warren, V. Barry, S. P. Hooker, X. Sui, T. S. Church and S. N. Blair, "Sedentary behaviors increase risk of cardiovascular disease mortality in men," *Med Sci Sports Exerc*, vol. 42, no. 5, pp. 879-885, 2010.

[2] I. H. Jonsdottir, L. Rödjer, E. Hadzibajramovic, M. Börjesson and G. Ahlborg Jr., "A prospective study of leisure-time physical activity and mental health in Swedish health care workers and social insurance officers," *Prev Med*, vol. 51, no. 5, pp. 373-377, 2010.

[3] M. G. H. Van Weering, "Towards a new treatment for chronic low back pain patients: using activity monitoring and personalized feedback," Ph.D. dissertation, Roessingh Res. & Dev.,Enschede, OV, 2011.

[4] R. Hawkins, M. Kreuter, K. Resnicow, M. Fishbein and A. Dijkstra, "Understanding tailoring in communicating about health," *Health Educ Res*, vol. 23, no. 3, pp. 454-466, 2008.

[5] E. a. Locke and G. P. Latham, "Building a practically useful theory of goal setting and task motivation: A 35-year odyssey.," *Am Psychol*, vol. 57, no. 9, pp. 705–717, 2002.

[6] S. Consolvo, P. Klasnja, D. W. McDonald, and J. a. Landay, "Goal-setting considerations for persuasive technologies that encourage physical activity," *Proc. Persuasive '09*, Claremont, CA, 2009.

[7] M. G. H. Dekker-van Weering, M. M. R. Vollenbroek-Hutten, and H. J. Hermens, "Do personalized feedback messages about activity patterns stimulate patients with chronic low back pain to change their activity behavior on a short term notice?," *Appl Psychophys Biof*, vol. 37, no. 2, pp. 81–89, Jun. 2012.

[8] R. M. H. Evering, T. M. Tönis, and M. M. R. Vollenbroek-Hutten, "Deviations in daily physical activity patterns in patients with the chronic fatigue syndrome: a case control study.," *J Psychosom Res*, vol. 71, no. 3, pp. 129–135, Sep. 2011.

[9] S. Noar, C. Benac and M. Harris, "Does tailoring matter? A meta-analytic review of tailored print health behaviour change interventions," *Psyc Bul*, vol. 133, no. 4, pp. 673-693, 2007.

[10] C. J. Greaves, K. E. Sheppard, C. Abraham, W. Hardeman, M. Roden, P. H. Evans, P. Schwarz, The IMAGE Study Group, "Systematic review of reviews of intervention components associated with increased effectiveness in dietary and physical activity interventions," *Public Health*, vol. 11., no. 119, pp. 1471-2458, 2011.

[11] R. Achterkamp, M. G. H. Dekker-Van Weering, M. Tabak, J. G. Timmerman, H. J. Hermens and M. M. R. Vollenbroek-Hutten, "Promoting a healthy lifestyle: how to improve long term adherence," to be published.

[12] W. M. Rodgers, P. M. Wilson, C. R. Hall, S. N. Fraser and T. C. Murray, "Evidence for a multidimensional self-efficacy for exercise scale," *Res Q Exercise Sport*, vol. 79, no. 2, pp. unknown, 2008.

[13] J. O. Prochaska and C. C. DiClemente, "Stages and processes of self-change and smoking: toward an integrative model of change," *J Consult Clin Psych*, vol 51, pp. 390-395, 1983.