

Technology based Interventions to Promote Healthy and Active Aging

The Role of Positive Emotions and Physical Activity

Miriam Cabrita^{1,2}, Monique Tabak^{1,2} and Miriam Vollenbroek-Hutten^{1,2}

¹Telemedicine Group, Roessingh Research and Development, Enschede, The Netherlands

²Telemedicine Group, Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, Enschede, The Netherlands

1 RESEARCH PROBLEM

The proportion of the global population aged above 60 years old is growing more rapidly than any other age group (World Health Organization (WHO), 2002, p. 6) creating several socio-economic challenges. Supporting independent living is a priority to enhance quality-of-life of the older population for as long as possible. Part of this support comes from the community and public health policies. However, a big part of the responsibility is for older citizens themselves to assume an active role in prevention and management of their health. Physical activity is very important to improve and maintain physical functioning in daily life. By physical activity, we mean not only exercising, but every type of movement during daily behaviour.

An active lifestyle is not limited to a high level of physical activity. The WHO defines Active Ageing as *“the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age”* (World Health Organization 2002). As such, older adults should maintain an active lifestyle, not only by means of physical activity, but also by being engaged in their social environments. This is achieved by engaging in leisure activities, contributing to the overall quality-of-life of the older adults. Although some individuals can achieve an active lifestyle by themselves, others seem to be in need of an external drive. One way to provide this external drive is through community-based interventions, such as buddy-based programs to walk in park, yoga lessons in the community centres or a daily TV show dedicated particularly to exercises for older adults. However, usually these community-based interventions fail to target individual needs that could better be matched in tailored interventions. The technological developments of the last years have given place to a new sort of interventions that, through the use of unobtrusive and ubiquitous technology, provide real-time recommendations

tailored to the current status of each individual. A mobile phone application that sends motivational messages based on current location or mood? A piece of art on the wall that changes colours when the physical activity is too low? A large screen that shows a funny companion that substitutes the conventional training coaches? The imagination is the limit. The current research intends to bring these technology-based interventions beyond the current state of the art by designing strategies to motivate people to be physically active through engagement in pleasant activities. Before developing technology, we need to understand the factors that influence a pleasant life and how they relate to physical activity in the daily lives of the older adults. That is the main focus of the presented PhD trajectory.

2 OUTLINE OF OBJECTIVES

The ultimate goal of this PhD trajectory is to *provide recommendations to design technology-based interventions to promote healthy and active ageing, thereby helping older adults to live independently for as long as possible*. Our approach aims at designing tailored interventions to be carried out in the daily lives, by helping older adults in being physically active and actively engaged in their social environments. To do so, we look at how physical activity relates to experience of positive emotions in the daily lives of older adults. This has three main reasons. First, the ‘upward spiral of lifestyle changes’ theory from Fredrickson defends that positive emotions act as openers for acceptance and adoption of new behaviours (Fredrickson 2013). Second, due to the fact that experience of positive emotions is inversely related to depression and anxiety (for a review see (Santos et al. 2013)), two major mental conditions among older adults. Last but not least, there is growing evidence supporting the link between positive emotions and overall health (e.g. (Pressman

& Cohen 2005; Chida & Steptoe 2008; Lamers et al. 2012)).

Based on this, we define the primary goal of this work by the following two objectives:

- *Objective 1:* Increase understanding on the relationship between positive emotions and physical health in daily lives of older adults living independently;
- *Objective 2:* Investigate how technology can support in monitoring and coaching towards active ageing in daily life.

3 STATE OF THE ART

The last decades have experienced the emergence of Positive Psychology, with attention being given to the promotion of positive emotions as a way to reach a pleasant life (Seligman et al. 2006). Several technology-based interventions have promoted positive emotions, for example, as a treatment or prevention of depression (e.g. (Proyer et al. 2014; Sin & Lyubomirsky 2009). However, to the best of our knowledge, the study of the link between physical activity and positive emotions is fairly new, especially in what concerns the older population. Participation in leisure activities increases overall levels of positive emotions (Onishi et al. 2006) and delays functional decline (Simone & Haas 2013), contributing to the support of independent living. Positive emotions are often forgotten when promoting physical activity among the older population (Phoenix & Orr 2014). Physical activities in daily living seem to enhance affective states also in the older population (Kanning et al. 2015). However, Kanning et al. did not look at the influence of daily environments on this relation. Do all activities contribute in the same way? What is the influence of the environment? Also, what is the effect of inactivity / sedentary behaviour in positive emotions? The answers to these questions will help us meeting *Objective 1*.

Technology plays a key role in supporting independent living and enhancing quality of life through monitoring, diagnosis/screening and treatment (Schulz et al. 2015). There is strong evidence for the effectiveness of technology-based interventions for promotion of physical activity (Fanning et al. 2012). Monitoring of physical activity is fairly easy due to the development of smaller and less obtrusive sensors that can be comfortably used in daily life. However, monitoring of positive emotions using technology is still in its infancy. Currently, most studies make use of experience sampling

techniques (Csikszentmihalyi & Larson 1987) to assess emotions in daily life.

Pleasure and enjoyment are mentioned by the older adults as one of the motivators to perform physical activity (Baert et al. 2011). However, to the best of our knowledge, enhancement of pleasure has not been explored in technology-based interventions to promote exercise or daily physical activity (i.e. physical activity obtained while performing daily activities). As physical activity contributes to an increase in the experience of positive emotions (Hogan et al. 2014; Kanning & Schlicht 2010; Bossmann et al. 2013), one can say that promotion of physical activity entails promotion of positive emotions. However, that is different than promoting physical activity based on what is pleasurable for each individual and, therefore, likely increasing adherence and motivation. This is the second gap that we aim to fill in by bringing technology to promote active ageing in daily life beyond its current state of the art (*Objective 2*).

4 METHODOLOGY

This PhD trajectory comprises a combination of theoretical, observational and modelling studies to achieve the goals abovementioned. In the following sections we provide a description of each step of the research.

4.1 Literature Study: Positive Emotions to Support Independent Living

With a systematic literature review, we evaluate whether, based on previous empirical studies, positive emotions are related to functional status of older adults, and consequently are relevant to the support of independent living. Particularly, we are interested in investigating how the ability to perform activities of daily living (ADL) independently relates to the experience of positive emotions on a daily basis. Eligibility criteria concern the study population (older adults living independently), the nature of intervention (observational, peer-reviewed papers investigating the relation between positive emotions and functional status) and outcome variables (studies that assessed ability to perform ADL – basic or instrumental, and exclusive measures of positive emotions – such as happiness, calmness and pleasure). Studies which consider a broader range of emotions (e.g. satisfaction with life) are excluded.

The study selection follows the PRISMA guidelines (Moher et al. 2014) and each step is taken under agreement among two or three researchers.

This theoretical study provides insights in (1) the relation between positive emotions and physical health of older adults (*Objective 1*), as well as in (2) the way in which technology can support bringing this understanding forward and support tailored interventions for promotion of Active Ageing (*Objective 2*).

4.2 Observational Studies: Positive Emotions and Physical Activity in Daily Life

During the presented PhD trajectory two longitudinal studies take place to investigate the relation between positive emotions and physical activity in the daily lives of older adults. We are interested to know what are the factors that contribute to a pleasant life and how we can make physical activity more pleasurable. Clearly, we are not able to change the social environments of the individuals (e.g. where a person lives or his or her marital status) but we can, instead, help individuals in finding what makes their life pleasurable in daily living and to promote specifically those activities. We hypothesize that what brings pleasure in daily life is highly personal. Therefore, the analysis of our studies will focus on a deep understanding in an individual level. In order to achieve this, our studies aim to gather a large amount of information for each individual subject. The participants in the study are in general active and engaged in the society. Our objective is to look at role models, what is called as positive deviance, look at when it works well to see how to motivate others to do the same.

In the first study we look exclusively at the relationship between positive emotions and physical activity in daily life (solid arrow in Figure 1). In the second study, we investigate how daily activities influence positive emotions, physical activity and the relation between positive emotions and physical activity (dashed arrows in Figure 1). In both studies data is gathered using self-assessment questionnaires, wearable technology and experience sampling on a smartphone.

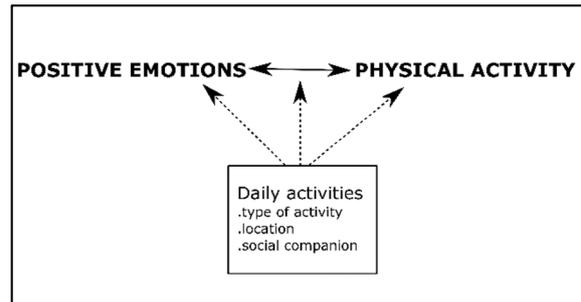


Figure 1: Relations investigated in the first (solid arrow) and second (dashed arrows) observational studies.

4.2.1 Investigating the Relation between Physical Activity and Positive Emotions

The main question we want to answer with this observational study is *which operationalization of daily physical activity relates the most to the experience of positive emotions in daily life: number of sedentary minutes, number of very active minutes or total number of steps in a day?* Additionally, we investigate whether the experience of positive emotions during a day relates stronger to physical activity on that day or on the following day. To answer these questions, we perform between- and within-individual analysis.

In this first study, participants ($n = 30$) wear a step counter during 4 weeks and every day, report on to which extend they experienced 6 positive emotions throughout the day. The emotions chosen were based on the modified Differential Emotions Scale (mDES, (Fredrickson et al. 2003)) to cover low- and high arousal emotions, such as relaxed and excited, respectively. The data analysis considers the overall experience of positive emotions and also the values of each discrete emotion.

4.2.2 Investigating the Influence of Daily Activities on Physical Activity, Positive Emotions and Relation between Physical Activity and Positive Emotions

With this second observational study we aim to answer the following questions:

- How do daily activities influence physical activity?*
- How do daily activities influence the experience of pleasure?*
- How do daily activities influence the relation between physical activity and pleasure?*

During approximately thirty days, participants ($n = 10$) are asked to answer questions approximately every hour – from 08h00 to 20h00 – on a smartphone reporting their current activity ('what are you doing?'), location ('where?'), social companion ('with whom?'), and the pleasure experienced while performing that activity (rated in a visual analogue scale and translated to a continuum from 0 to 10). Additionally, participants carry a hip worn accelerometer during the time of the experiment.

To answer question *a*), we categorize the physical activity level of each day as 'Inactive', 'Moderately Active' and 'Highly Active' using the K-means clustering algorithm. The clustering analysis is performed within-individual in contrast to using pre-defined cut-off points. Next, we categorized the answers of ES-events in four properties, each one with several values as follows: 'location' (values: outdoors or indoors), 'social companion' (values: alone, with partner, with family, with friends or colleagues and unknown), 'type of activity' (values: go out or relaxation, commuting, eat or care, association, household and work or study) and 'time' (values: each one of the weekdays). Finally, we investigate the relation between the daily physical activity level and the relative frequency of ES-events with each value registered per day.

Questions *b*) and *c*) are answered through multi-level models with ES-events nested within subjects.

4.3 Modelling: Simulation Study Combining Information Acquired

The last step is to propose a model to support the technical implementation of tailored technology-based interventions for promotion of healthy and active ageing. The parameters and relations to be included in the model depend on the results of the theoretical and observational studies. The intention is to provide (real-time) motivational messages that will help older adults reaching an active lifestyle. Therefore we build upon current models of tailoring motivational messages for promotion of physical activity (op den Akker et al. 2015). We also look at the state of the art of ontologies for identification of human behaviour and for support of behaviour change. Furthermore, this model should be able to continuously adapt to the user in order to follow possible functional decline or changes based on life events.

This technical study intends to answer two research questions:

- a. What is the minimum time interval that we should monitor an individual to be able to have a reliable*

model on the relation between physical activity and positive emotions in daily life using the setup from the previous experiments?

- b. What are the parameters and relations of a model to provide motivational messages based on the information gathered in the previous studies?*

5 EXPECTED OUTCOME

5.1 Literature Study: Positive Emotions to Support Independent Living

The systematic review was conducted up to May 2015 using the PsycINFO, Scopus and PubMed electronic databases. From the 963 unique results retrieved, 10 papers met the inclusion criteria and were therefore selected for further analysis. Relevant data was summarized in standardized tables previously agreed on by two authors. Both cross-sectional ($n=5$) and longitudinal papers provided evidence for a relation between positive emotions and functional status. The longitudinal studies suggest a bi-directional relation with lower experience of positive emotions predicting functional decline, but also, with higher functioning predicting higher experience of positive emotions at follow-up. Differences were found based on age, culture and gender. Our findings support the potential value of a holistic approach promoting physical activity and positive emotions for supporting independent living. This work was submitted and is currently under revision.

5.2 Observational Studies: Positive Emotions and Physical Activity in Daily Life

5.2.1 Investigating Relation between Physical Activity and Positive Emotions

This study is planned to start in February 2016. We expect to find individual differences on the relation between physical activity and positive emotions in daily life. While for some people bouts of vigorous activity might provide an increased experience of positive emotions during the day (operationalization: number of very active minutes), others might benefit from a more cumulative and balanced activity throughout the day (operationalization: total number of steps). Based on our previous experience, we

hypothesize that, in general, an increase in daily physical activity is related to higher positive emotions. In our analysis, we will look at a global score of positive emotions but also at discrete emotions related to both low- and high arousal, such as calmness and excitement, respectively.

5.2.2 Investigating Influence of Daily Activities on Physical Activity, Positive Emotions and Relation between

This study took place between November 2014 and December 2015 with ten older adults (aged 65 to 83) during approximately 33 days (range 24 – 38). A total of 3735 experience sampling (ES) events were collected. The data analysis is ongoing as follows.

a. How do daily activities influence physical activity?

The data of the first 5 participants in the study was used to answer this question, providing a total of 146 days and 1534 ES-events. Our results suggest that location, social companion, type of activity and day of the week do significantly influence the daily activity level of the participants. For example, being more outside the home ('outdoors') increases the likelihood of having a highly active day comparing to an inactive day. Also, being with friends or colleagues seems to increase the likelihood of having a moderately active day when compared to inactive day. The results of this work can be found at (Cabrita et al. 2015). The same data analysis will be performed with the data from all participants but no significant differences are to be expected.

b. How do daily activities influence experience of pleasure?

c. How do daily activities influence the relation between physical activity and pleasure?

The data of ten participants is currently being analysed with multi-level modelling to answer question *b)* and *c)*. We expect that generally, activities performed outside the house and with other people will be the most pleasurable. However, we expect differences between individuals.

5.3 Modelling: Simulation Study Combining Information Acquired

This part of the work will start in March 2016 and it is currently in the ideation phase. The outcome of this study is strongly dependent on the results of the literature and observational studies, as they serve as input to decide on the parameters and relations to be included in the model. The model should be implemented in the new version of the Activity

Coach, a mobile system developed at Roessingh Research and Development to motivate people to become more active (Op den Akker et al. 2012).

6 STAGE OF THE RESEARCH

At the current moment (February 2016) the literature study is finished and submitted. The data acquisition of one of the observational studies is completed, and its data is being analysed. The lessons learnt so far on each one of the objectives can be summarized as follows in the rest of this section.

- *Objective 1: Increase understanding on the relation between positive emotions and physical health in daily lives of older adults living independently;*

The results of the literature review suggest that, independently of the cause-effect direction, positive emotions and functional status do relate in daily life. This means that, by promoting positive emotions in daily life, we are contributing for the general health and supporting independent living of older adults. Furthermore, in this theoretical study we see that the strength of the relation between positive emotions and functional status highly relates to demographic aspects as gender, age and culture. Also, preliminary analysis of one observational study suggest that the influence of daily environments on the experience of positive emotions and physical activity is highly personal.

- *Objective 2: Investigate how technology can support in monitoring and coaching active ageing in daily life.*

The findings in objective 1 reinforce the need for tailored interventions. For example, based on the results of the second observational study, when classifying the level of activity of a certain day, it does not seem appropriate to select a predefined cut-off for the older population. Instead, one should look at within individual data. This is important for example when setting goals as, according to the Goal-Setting Theory, when thriving for best results one should set challenging but achievable goals ((Locke & Latham 2002)). Also, the same study suggests that, instead of motivating people to get physically active, a coaching strategy could thus be to motivate people to engage in outdoor- or social activities, increasing physical activity indirectly. This motivation by proxy could add to the diversity of coaching of such systems and potentially increase adherence and pleasure in using the system. This information will be combined with the results of the other two points of this study

in order to provide recommendation for pleasurable activities that increase the physical activity level.

Our results also provide information on how technology can be used in research to improve the knowledge on the field. The results of the literature study suggest that there is a need of incorporating more objective measures of functioning in research. All the studies included in the literature review used paper based questionnaires, vulnerable to the subjectivity (and sometimes, optimism) of the participants. The use of GPS or wearable technology in this type of research might provide different results. Furthermore, there is a clear need for longitudinal research and with more continuous data collection. This can be achieved with home monitoring or experience sampling. Only in this way we will be able to follow the functional decline when it occurs. One single assessment is not able to evaluate how physical and mental health relate over time.

REFERENCES

- Baert, V. et al., 2011. Motivators and barriers for physical activity in the oldest old: a systematic review. *Ageing research reviews*, 10(4), pp.464–74. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21570493> [Accessed September 5, 2014].
- Bossmann, T. et al., 2013. The Association between Short Periods of Everyday Life Activities and Affective States: A Replication Study Using Ambulatory Assessment. *Frontiers in psychology*, 4(April), p.102. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3625722&tool=pmcentrez&rendertype=abstract> [Accessed March 11, 2014].
- Cabrera, M. et al., 2015. An Unobtrusive System to Monitor Physical Functioning of the Older Adults: Results of a Pilot Study. In *International Workshop on Personalization and Adaptation in Technology for Health 2015 (PATH 2015) held in conjunction with the 23rd Conference on User Modelling, Adaptation and Personalisation (UMAP 2015)*. Dublin, Ireland: R. Piskac c/o Redaktion Sun SITE, Informatik V, RWTH Aachen., pp. 1–12. Available at: <http://ceur-ws.org/Vol-1388/PATH2015-paper1.pdf>.
- Chida, Y. & Steptoe, A., 2008. Positive psychological well-being and mortality: a quantitative review of prospective observational studies. *Psychosomatic medicine*, 70(7), pp.741–56. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18725425> [Accessed January 26, 2014].
- Csikszentmihalyi, M. & Larson, R., 1987. Validity and reliability of the Experience-Sampling Method. *The Journal of nervous and mental disease*, 175(9), pp.526–36. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3655778> [Accessed March 19, 2015].
- Fanning, J., Mullen, S.P. & Mcauley, E., 2012. Increasing physical activity with mobile devices: A meta-analysis. *Journal of Medical Internet Research*, 14(6), pp.1–11.
- Fredrickson, B.L., 2013. *Positive Emotions Broaden and Build* 1st ed., Copyright © 2013, Elsevier Inc. All rights reserved. Available at: <http://dx.doi.org/10.1016/B978-0-12-407236-7.00001-2>.
- Fredrickson, B.L. et al., 2003. What Good are Positive Emotions in crises? A Prospective Study of Resilience and Emotions Following the Terrorist Attacks on the United States on September 11th, 2001. *J Pers Soc Psychol*, 84(2), pp.365–376. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2755263&tool=pmcentrez&rendertype=abstract>.
- Hogan, C.L. et al., 2014. Beyond emotional benefits: Physical activity and sedentary behaviour affect psychosocial resources through emotions. *Psychology & health*, 0446(November), pp.1–31. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/25307453>.
- Kanning, M., Ebner-Priemer, U.W. & Schlicht, W., 2015. Using activity triggered e-diaries to reveal the associations between physical activity and affective states in older adult's daily living. *International Journal of Behavioral Nutrition and Physical Activity*, 12(1), p.111. Available at: <http://www.ijbnpa.org/content/12/1/111>.
- Kanning, M. & Schlicht, W., 2010. Be active and become happy: an ecological momentary assessment of physical activity and mood. *Journal of sport & exercise psychology*, 32(2), pp.253–61. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20479481>.
- Lamers, S.M.A. et al., 2012. The impact of emotional well-being on long-term recovery and survival in physical illness: A meta-analysis. *Journal of Behavioral Medicine*, 35(5), pp.538–547.
- Locke, E. a. & Latham, G.P., 2002. Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American Psychologist*, 57(9), pp.705–717. Available at: <http://doi.apa.org/getdoi.cfm?doi=10.1037/0003-066X.57.9.705> [Accessed March 1, 2013].
- Moher, D. et al., 2014. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: *Annals of Internal Medicine*, 151(2), pp.264–269.
- Onishi, J. et al., 2006. The pleasurable recreational activities among community-dwelling older adults. *Archives of gerontology and geriatrics*, 43(2), pp.147–55. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16368155> [Accessed November 10, 2014].
- Op den Akker, H. et al., 2012. Development and Evaluation of a Sensor-Based System for Remote Monitoring and Treatment of Chronic Diseases. In *6th International Symposium on eHealth Services and Technologies*. Geneva, Switzerland: SciTePress - Science and Technology Publications, pp. 19–27.
- op den Akker, H. et al., 2015. Tailored motivational message generation: A model and practical framework for real-time physical activity coaching. *Journal of Biomedical Informatics*, 55, pp.104–115. Available at: <http://dx.doi.org/10.1016/j.jbi.2015.03.005>.

- Phoenix, C. & Orr, N., 2014. Pleasure: a forgotten dimension of physical activity in older age. *Social science & medicine* (1982), 115, pp.94–102. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24955874> [Accessed November 10, 2014].
- Pressman, S.D. & Cohen, S., 2005. Does positive affect influence health? *Psychological bulletin*, 131(6), pp.925–971.
- Proyer, R.T. et al., 2014. Positive psychology interventions in people aged 50-79 years: long-term effects of placebo-controlled online interventions on well-being and depression. *Aging & Mental Health*, (September), pp.37–41. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24712501> [Accessed September 4, 2014].
- Santos, V. et al., 2013. The role of positive emotion and contributions of positive psychology in depression treatment: systematic review. *Clinical practice and epidemiology in mental health : CP & EMH*, 9, pp.221–37. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3866689&tool=pmcentrez&rendertype=abstract>.
- Schulz, R. et al., 2015. Advancing the Aging and Technology Agenda in Gerontology. *The Gerontologist*, 55(5), pp.724–734. Available at: <http://gerontologist.oxfordjournals.org/lookup/doi/10.1093/geront/gnu071>.
- Seligman, M.E.P., Rashid, T. & Parks, A.C., 2006. Positive Psychotherapy. *American Psych*, (November), pp.774–788.
- Simone, P.M. & Haas, A.L., 2013. Frailty, Leisure Activity and Functional Status in Older Adults: Relationship With Subjective Well Being. *Clinical Gerontologist*, 36(4), pp.275–293. Available at: <http://www.scopus.com/inward/record.url?eid=2-s2.0-84879128385&partnerID=tZOtx3y1> [Accessed June 1, 2015].
- Sin, N.L. & Lyubomirsky, S., 2009. Enhancing Well-Being and Alleviating Depressive Symptoms With Positive Psychology Interventions: a practice-friendly meta-analysis. *Journal of Clinical Psychology*, 65(5), pp.467–487.
- World Health Organization, 2002. *Active Ageing: A Policy Framework*, Madrid, Spain. Available at: http://whqlib.doc.who.int/hq/2002/who_nmh_nph_02.8.pdf.