

Health Behaviour Change Support Systems: Past Research and Future Challenges

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The emergence of mobile devices and social technologies has opened up new possibilities for health promotion and disease prevention. By means of emotional stimuli, motivation, and persuasion health behaviour change support systems (HBCSS) aim at influencing users to improve their health and wellbeing. This article presents the results of a bibliometric analysis related to the existing HBCSS body of knowledge. A total of 51 research studies were analysed with a look at their topical and theoretical focus. It was found that the majority of studies emphasize a rather technological view of behavioural change as opposed to a psychological or social view. In addition, the identified theories underlying the design of HBCSS frequently assume full rational behaviour of individuals. Based on these findings, four avenues for future research and novel trains of thought related to HBCSS are discussed.

Keywords

E-health, health behaviour change support systems, literature review, persuasive computing.

1. Introduction

Health behaviour change support systems (HBCSS) are software applications targeted to induce an alteration of attitude and/or change in people's behaviour toward healthier life styles. It is an integral part of what is known as *persuasive computing* or *human-centric computing* and as such not only related to computer and information science but also to other disciplines such as sociology, psychology, or cognitive sciences. HBCSS are applied in many different areas, such as in the promotion of exercise and healthy eating choices [1-3], cessation of smoking [4], monitoring of sleep disorders, or other physical and mental health related issues.

With the broad availability of smartphones, tablets, and sensor-based devices, the design of HBCSS has shifted from traditional software applications (apps) to more ubiquitous and social web-based solutions [5]. However, while the technical design has been adapted to the new realities of users, the underlying assumptions and behaviour change theories that inform the software design have not been adapted in a similar pace since the emergence of HBCSS [6].

With the aim to identify potential research gaps and discuss emerging challenges, we conduct a bibliometric study consisting of a topical analysis and a co-citation network analysis of the extant literature on HBCSS. In particular, we want to investigate (i) which behavioural or design theories are applied to achieve the goal of influencing users, (ii) what conditional and unconditional assumptions these theories implicate, and (iii) what strategies are used to attain continued usage. Based on our findings, we then deduce research challenges and emerging research topics that are relevant to HBCSS.

2. Material and Methods

In order to explore how current research addresses the formation, modification, and reinforcement of behavioural changes in health and wellbeing apps, we conducted a scoping review of the available literature [7] in MEDLINE and Web of Science. Since HBCSS are known under many different labels, we used multiple keywords like 'persuasive computing', 'persuasive system', 'persuasive software' (and other terms relating to technology), in combination with 'health', 'wellbeing' or 'behaviour change'. As of December 2014, our initial search yielded 76 matches. In a second step, a screening of the search result was conducted. Inclusion of a study in the review was rooted on our subjective decision

based on the following criteria: (a) the article reports on the design, implementation, or use of a persuasive system, and (b) the behavioural changes are related to an improvement of health or wellbeing. According to the criteria defined, we obtained a list of 51 studies (cf. Appendix A). We then performed a topical analysis and a co-citation network analysis of the identified literature and the references cited in the reviewed articles. The former is performed with the purpose to discovering relevant themes in the literature. The latter is used for identifying the most influencing references and theoretical streams in the available literature.

As a basis for our analyses, we used the Science of Science (Sci2) tool [8] for exploring the identified knowledge base. The Sci2 tool is a modular toolset specifically designed for bibliometric studies. It supports a great variety of analyses such as temporal, geospatial, topical, and network analysis. The tool also allows the researcher to present large amounts of data using integrated and external data visualization services.

3. Review Results

HBCSS studies have been published in diverse fields, such as brain research, social sciences, electrical engineering, computer science, or health professions (cf. Appendix B). As it is shown in Figure 1, it is a relatively young area of research that needs to mature.

The first article [9] we found that discussed about persuasive technology and aspects of health behaviour change was published in 1999. discuss emerging challenges After some years of relative silence, in 2006 there was an increase in publications due to the inauguration of the international conference series on persuasive technology for human well-being, first conducted in 2006. Since then only a moderate increase of papers is observed. In 2013, the topic regained attention because of a special issue on ambient assisted living for mobility in the personal and ubiquitous computing journal. A large number of the identified articles are published in the mentioned two outlets.

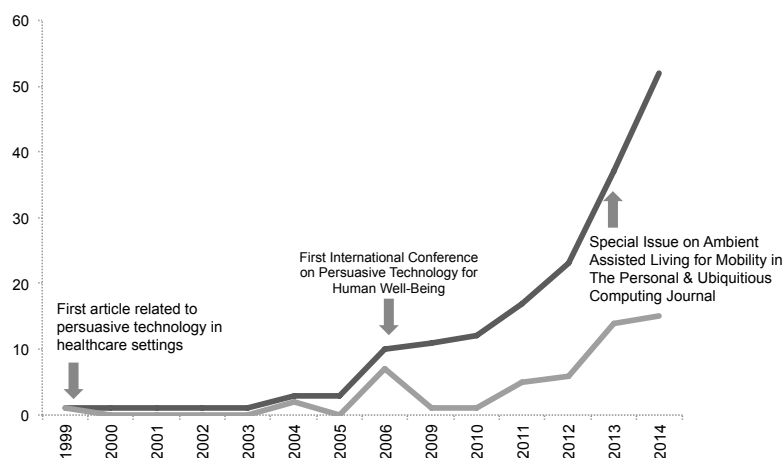


Figure 1 Identified studies on HBCSS with respect to its year of publication.

In the subsequent section, we first discuss the results of a topical analysis that we performed with the intention to discover the most important themes, which drive current research. After that, we present the results of the co-citation network analysis in order to discuss influential references in HBCSS as well as the underlying theoretical assumptions of the frequently cited literature.

3.1 Topical Focus of Current HBCSS Studies

The purpose of a topical analysis is to determine the topic coverage within a body of text or across multiple textual resources. The main goal is to understand the topical distribution, i.e. what topics are covered and how much of each topic is covered [10]. We used the text normalization algorithms provided by the Sci2 tool to tokenize, stem, and remove unnecessary pre- and suffixes within the

3.2 Theoretical Focus of Current HBCSS Studies

To get an understanding of the core theoretical fundament to study and motivate the design of HBCSS studies, we conducted a co-citation network analysis of all the references (including journal articles, books, book sections, and conference papers) that were cited in the 51 identified studies. We used the Sci2 tool to extract a directed paper network that is weighted in terms of number of citations within our dataset. Figure 3 shows the most influential publications in current HBCSS studies by means of a force-directed layout, which we sketch with the Gephi software package. Based on this initial illustration of most influential studies, we then reviewed the theoretical fundament used in these publications for motivating and explaining behaviour change.

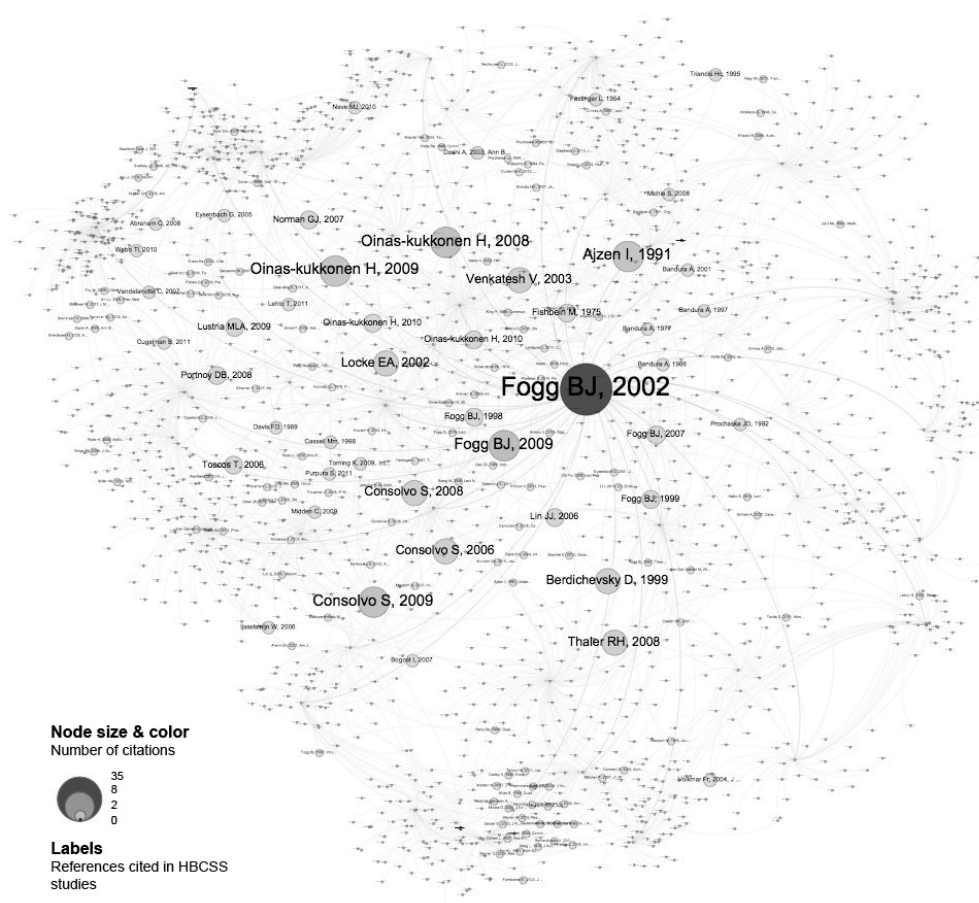


Figure 3 Most cited studies in the 51 identified HBCSS studies. Nodes are sized and coloured based on the number of overall citation.

The most cited work in HBCSS studies is the seminal book by BJ Fogg [23], which introduced the notion of persuasion as part of software design. Early studies have followed the conception that software developers always influence their users in one way or another. In doing so, they have frequently relied upon the *operant conditioning theory* [24], which assumes that a behavioural change toward healthier lifestyles can be achieved by rewarding favoured behaviour and by punishing negative behaviour. The basic assumption behind operant conditioning theory is that users react based on their experiences of antecedents and consequences, instead of a reflexive reaction to a stimulus. Accordingly, another subliminal assumption is that the user—to some extent—is rational in his/her choice and subsequent behaviour. Operant conditioning is frequently found in exercise and physical fitness apps, which try to motivate users by giving them “virtual” rewards for a more active lifestyle.

The same “rational man” assumption is shared by the *theory of reasoned action* and *theory of planned behaviour* [25, 26], which are also widely used in HBCSS. In both theories it is assumed that

behaviour is the result of a more or less conscious appreciation of values related to the system's utility and ease of use. Hence, users' attitude and perception are major drivers to an intended behaviour, which itself is a precursor of actual user behaviour. Over the years, several theoretical additions have been introduced (e.g. the role of social influence, gender, age, experience), which improved the accuracy of predicting technology acceptance and ultimately lead to a unified theory of acceptance and use of technology [27]. Overall, the mentioned theories describe little about psychological cues that influence users to change their health-related behaviour. Rather, and in line with the dominant technical focus of the identified papers, these theories are useful for predicting acceptance of system features and systems design.

Attitudes, beliefs, and perception of individuals play also an important in the *cognitive dissonance theory* [28], which also is applied in some of the HBCSS studies. It deals with the fact that many individuals feel uneasy when their beliefs and opinions are inconsistent with their actions. This creates a state of "dissonance", which may become in a certain point of time quite unbearable, motivating a person to actively change his/her behaviour in order to restore cognitive consistency. Smoking cessation apps frequently make use of this effect.

Lastly, we found that several studies work with the *goal setting theory* [29, 30]. It is based on the assumption that individuals have an intrinsic motivation to reach a clearly defined goal or feel that it is important to change their current behaviour. Unlike with the operant conditioning theory, which uses rewards as means for encouraging individuals, goal setting frequently is applied without any additional incentive structure since it assumes that users feel rewarded by the simple fact that they achieved the goal. However, the strength of this motivational effect may vary depending on the difficulty, proximity, and specificity of the goal. Goal setting is often used in diet and fitness apps.

4. Directions for Future Research

Based on the review of the literature, we propose to carefully consider the following research challenges while designing and/or evaluating HBCSS.

4.1 Rational Design Versus Emotional Design

In spite of the fact that recent research has raised serious questions about the human rationality of judgment and decision-making [31], the review of the literature has shown that many of the behavioural theories used in current HBCSS studies base on the assumption of rational users. Evidence exists that not only conscious, rational reactions influence behaviour, but oftentimes rather unconscious, emotional processes [32]. Anger, fear, envy, sympathy or pleasure are important cues for influencing the behaviour of users. Accordingly, the identification of design principles that help to systematically elicit emotional responses for facilitating the intended health-related behaviour changes could represent an important research theme for the future.

4.2 Habitual Design Versus Interface Design

As described before, we found a strong technical focus in the available literature, frequently directed toward interface design and subsequently testing acceptance of the developed solution. While interfaces design certainly is an important topic for HBCSS, we feel that there is a need to additionally emphasize what we refer to as "habitual design", i.e. the procedures and strategies to develop or disrupt habits that may lead to the intended behavioural changes. Habits can be perceived as goal-directed automaticity [33] and as such considerably guide performance of a behaviour [34]. Habits also have a significant impact on the acceptance of new systems [35]. However, little is actually known about the mechanics how to successfully create habits through software design [36]. We believe that this is important as habitual design may not only be crucial for effectively generating the intended perpetual effects (e.g. more physical exercising, cessation of alcohol use, healthier eating), but also for improving long-term acceptance and continued use of HBCSS which takes us to our next research challenge.

4.3 Securing Long-term Motivation and Continued Usage

Since behavioural changes don't occur instantaneously, HBCSS only work when the user is willing to use the system over a longer period of time. Together with the creation of habitual use patterns it is therefore of utmost importance to also integrate different kinds of stimulatory measures to ensure long-term motivation of users, which to our view seems to be one of the hardest problems to solve as this significantly also depends on contextual influences as described next.

4.4 Contextualization of User, Use, and Utility of Design

In the reviewed literature we found barely any approaches for contextualizing both technical and social design of the proposed HBCSS. As we mentioned before, contextually anchored research is important in order to (i) attain the intended effects and (ii) to better understand the capacities and limitations of a system. We cannot assume that the implemented measures for persuasion, motivation, reputation or coercion work for all users and for all use scenarios. Demographic, cultural, economic, and psychosocial differences may critically influence the effects [37], and ultimately utility of HBCSS. Both development and evaluation instruments need to take this into consideration and provide flexible mechanisms for adaptation and learning (e.g. [34]).

5. Conclusions

HBCSS are exciting developments in health informatics because they provide a new way how to influence the attitude and/or change people's behaviour toward healthier life styles. In this paper, we have analysed the topical and theoretical focus of 51 HBCSS studies and put forward four themes for future research. We found that a stronger emphasis on emotional and habitual design principles is needed as compared to currently predominant rather rational and technical design approaches. We also identified a need for further research that on the one hand embeds contextual parameter as part of the design, and on the other hand describes practical strategies for securing long-term motivation of users.

Throughout this discussion of HBCSS, it must be recognized that this field of research emerged in the past ten years and is therefore relatively young (cf. Appendix A). We are still at the beginning of what promises to be a major facilitator for health promotion and disease prevention. If we compare how much technology has changed our ways of doing daily routine activities and generally our lifestyles, we can expect to witness major progress in the years to come with respect to contextual, emotional, and habitual design of HBCSS.

Acknowledgement

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Appendix A: Complete List of Reviewed Literature on HBCSS

Authors	Title	Journal Title	Year
Azar, KMJ.; Lesser, LI.; Laing, BY.; Stephens, J.; Aurora, MS.; Burke, LE.; Palaniappan, LP	Mobile Applications for Weight Management Theory-Based Content Analysis	American Journal of Preventive Medicine	2013
Banos, RM.; Cebolla, A.; Botella, C.; Garcia-Palacios, A.; Oliver, E.; Zaragoza, I.; Alcaniz, M	Improving Childhood Obesity Treatment Using New Technologies: The ETIOBE System.	Clinical Practice and Epidemiology in Mental Health	2011
Berdichevsky, D.; Neunschwander, E	Toward an ethics of persuasive technology - Ask yourself whether your technology persuades users to do something you wouldn't want to be persuaded to do yourself.	Communications of the ACM	1999
Berkovsky, S.; Freyne, J.; Coombe, M	Physical Activity Motivating Games: Be Active and Get Your Own Reward	ACM Transactions on Computer-Human Interaction	2012
Casey, M.; Hayes, PS.; Murphy, AW.; Glynn, L.; Glynn, F.; Laighin, GO.; Heaney, D	Patients' experiences of using a smartphone application to increase physical activity: the SMART MOVE qualitative study in primary care	British Journal of General Practice	2014
Chan, AS	Health captology--application of persuasive technologies to health care.	Studies in Health Technology and Informatics	2004
Chiang, JH.; Yang, PC.; Tu, H	Pattern analysis in daily physical activity data for personal health management	Pervasive and Mobile Computing	2014
Chiu, MC.; Chen, CCH.; Chang, SP.; Chu, HH.; Wang, C.; Hsiao, FH.; Huang, P	Motivating the motivators: Lessons learned from the design and evaluation of a social persuasion system	Pervasive and Mobile Computing	2014

Authors	Title	Journal Title	Year
Chomutare, T.; Tatara, N.; Arsand, E.; Hartvigsen, G	Designing a diabetes mobile application with social network support.	Studies in Health Technology and Informatics	2013
Comber, R.; Thieme, A	Designing beyond habit: opening space for improved recycling and food waste behaviors through processes of persuasion, social influence and aversive affect	Personal and Ubiquitous Computing	2013
Cugelman, B.; Thelwall, M.; Dawes, P	Online Interventions for Social Marketing Health Behavior Change Campaigns: A Meta-Analysis of Psychological Architectures and Adherence Factors	Journal of Medical Internet Research	2011
Dorrestijn, S.; Verbeek, PP	Technology, Wellbeing, and Freedom: The Legacy of Utopian Design	International Journal of Design	2013
Fozard, J.L.; Kearns, WD	Persuasive GERONtechnology: Reaping technology's coaching benefits at older age	Persuasive Technology	2006
Gasca, E.; Favela, J.; Tentori, M Guthrie, CF	Assisting Support Groups of Patients with Chronic Diseases through Persuasive Computing Smart Technology and the Moral Life	Journal of Universal Computer Science Ethics & Behavior	2009 2013
IJsselstein, W.; de Kort, Y.; Midden, C.; Eggen, B.; van den Hoven, E	Persuasive technology for human well-being: Setting the scene	Persuasive Technology	2006
Intille, SS	A new research challenge: Persuasive technology to motivate healthy aging	IEEE Transactions on Information Technology in Biomedicine	2004
Iyengar, MS.; Fjorez-Arango, JF	Decreasing workload among community health workers using interactive, structured, rich-media guidelines on smartphones	Technology and Health Care	2013
Kaptein, M.; van Halteren, A	Adaptive persuasive messaging to increase service retention: using persuasion profiles to increase the effectiveness of email reminders	Personal and Ubiquitous Computing	2013
Kelders, SM.; Kok, RN.; Ossebaard, HC.; Van Gemert-Pijnen, JEW C	Persuasive System Design Does Matter: A Systematic Review of Adherence to Web-Based Interventions	Journal of Medical Internet Research	2012
Khaled, R.; Barr, P.; Noble, J.; Biddle, R	Investigating social software as persuasive technology	Persuasive Technology	2006
Khaled, R.; Barr, P.; Noble, J.; Fischer, R.; Biddle, R	Our place or mine? Exploration into collectivism-focused persuasive technology design	Persuasive Technology	2006
Khalil, A.; Abdallah, S	Harnessing social dynamics through persuasive technology to promote healthier lifestyle	Computers in Human Behavior	2013
Klaassen, R.; den Akker, RO.; Lavrysen, T.; van Wissen, S	User preferences for multi-device context-aware feedback in a digital coaching system	Journal on Multimodal User Interfaces	2013
Klein, M.; Mogles, N.; van Wissen, A	Intelligent mobile support for therapy adherence and behavior change	Journal of Biomedical Informatics	2014
Koivisto, J.; Hamari, J	Demographic differences in perceived benefits from gamification	Computers in Human Behavior	2014
Lee, D.; Helal, S.; Anton, S.; De Deugd, S.; Smith, A	Participatory and Persuasive Telehealth	Gerontology	2012
Lehto, T.; Oinas-Kukkonen, H	Persuasive Features in Web-Based Alcohol and Smoking Interventions: A Systematic Review of the Literature	Journal of Medical Internet Research	2011
McCreadie, C.; Raper, J.; Gunesh, A.; Wood, J.; Carey, K.; Petrie, H.; Wood, L.; Survey, O.; Tyler, S.; Biggs, S	Persuasive technology for leisure and health: Development of a personal navigation tool	Persuasive Technology	2006
McMahon, S.; Vankipuram, M.; Hekler, EB.; Fleury, J	Design and evaluation of theory-informed technology to augment a wellness motivation intervention	Translational Behavioral Medicine	2014

Authors	Title	Journal Title	Year
Mintz, J	Additional key factors mediating the use of a mobile technology tool designed to develop social and life skills in children with Autism Spectrum Disorders: Evaluation of the 2nd HANDS prototype	Computers & Education	2013
Mintz, J.; Branch, C.; March, C.; Lerman, S	Key factors mediating the use of a mobile technology tool designed to develop social and life skills in children with Autistic Spectrum Disorders	Computers & Education	2012
Munson, SA.; Cavusoglu, H.; Frisch, L.; Fels, S	Sociotechnical Challenges and Progress in Using Social Media for Health	Journal of Medical Internet Research	2013
Nakajima, T.; Lehdonvirta, V	Designing motivation using persuasive ambient mirrors	Personal and Ubiquitous Computing	2013
Nguyen, H.; Masthoff, J	Towards an architecture for an adaptive persuasive system	Persuasive Technology	2006
Oduor, M.; Alahaivala, T.; Oinas-Kukkonen, H	Persuasive software design patterns for social influence	Personal and Ubiquitous Computing	2014
Ohrstrom, P	Helping Autism-Diagnosed Teenagers Navigate and Develop Socially Using E-Learning Based on Mobile Persuasion	International Review of Research in Open and Distance Learning	2011
Oinas-Kukkonen, H	A foundation for the study of behavior change support systems	Personal and Ubiquitous Computing	2013
Orji, R.; Mandryk, RL	Developing culturally relevant design guidelines for encouraging healthy eating behaviour	International Journal of Human-Computer Studies	2014
Redstrom, J	Persuasive design: Fringes and foundations	Persuasive Technology	2006
Rodriguez, MD.; Roa, JR.; Moran, AL.; Nava-Munoz, S	CAMMInA: a mobile ambient information system to motivate elders to exercise	Personal and Ubiquitous Computing	2013
Saparova, D	Motivating, influencing, and persuading patients through personal health records: a scoping review.	Perspectives in Health Information Management	2012
Tieben, R.; Sturm, J.; Bekker, T.; Schouten, B	Playful persuasion: Designing for ambient playful interactions in public spaces	Journal of Ambient Intelligence and Smart Environments	2014
van Leer, E.; Connor, NP	Use of Portable Digital Media Players Increases Patient Motivation and Practice in Voice Therapy	Journal of Voice	2012
van Limburg, M.; van Gemert-Pijnen, JEW.C.; Nijland, N.; Ossebaard, HC.; Hendrix, RMG.; Seydel, ER	Why Business Modeling is Crucial in the Development of eHealth Technologies	Journal of Medical Internet Research	2011
VanDeMark, NR.; Burrell, NR.; LaMendola, WF.; Hoich, CA.; Berg, NP.; Medina, E	An exploratory study of engagement in a technology-supported substance abuse intervention	Substance Abuse Treatment Prevention and Policy	2010
Vidyarthi, J.; Riecke, BE	Interactively mediating experiences of mindfulness meditation	International Journal of Human-Computer Studies	2014
Wiafe, I.; Nakata, K.; Gulliver, S	Categorizing users in behavior change support systems based on cognitive dissonance	Personal and Ubiquitous Computing	2014
Wohl, MJA.; Parush, A.; Kim, HS.; Warren, K	Building it better: Applying human-computer interaction and persuasive system design principles to a monetary limit tool improves responsible gambling	Computers in Human Behavior	2014
Xu, A.; Chomutare, T.; Iyengar, S	Persuasive attributes of medication adherence interventions for older adults: A systematic review	Technology and Health Care	2014
Zuckerman, O.; Gal-Oz, A	Deconstructing gamification: evaluating the effectiveness of continuous measurement, virtual rewards, and social comparison for promoting physical activity	Personal and Ubiquitous Computing	2014

Appendix B: HBCSS Research in Disciplinary Journals

