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Chapter 7

The impact of patient-centered eHealth applications on patient outcomes: a review on the mediating influence of Human Factor issues on study results

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Abstract

Objectives: To examine the evidence on the impact of patient-centered eHealth applications on patient care and to analyze if and how reported human factor issues mediated the outcomes.

Methods: We searched PUBMED (2014-2015) for studies evaluating the impact of patient-centered eHealth applications on patient care (behavior change, self-efficacy and patient health related outcomes).

Results: Of the 348 potentially relevant papers, 10 papers were included for data analysis. None of the 10 papers reported a negative impact of the eHealth intervention. Seven papers involved a randomized controlled trial (RCT) study. Six of these RCT's reported a positive impact of the eHealth intervention on patient care. The Systems Engineering Initiative for Patient Safety (SEIPS 2.0) model was used as a guidance framework to identify the reported human factors possibly impacting the effectiveness of an eHealth intervention. All 10 papers reported on human factor issues *possibly* mediating effects of patient-centered eHealth. Human factors involved patient characteristics, perceived social support and (type of) interaction between patient and provider.

Conclusion: While the amount of patient-centered eHealth interventions increases, many questions remain as to what and to what extent human factors mediate their use and impact. Future research should adopt a formal theory-driven approach towards human factors, when investigating those factors' influence on the effectiveness of these interventions. Insights could then be used to better tailor the content and design of eHealth solutions to different patient user profiles, so as to enhance eHealth interventions impact on patient behavior, self-efficacy and health related outcomes.

Keywords: eHealth, health related outcome, behavior change, self-efficacy, patients, impact

1. Introduction

To improve healthcare delivery, governments and healthcare organizations worldwide are investing considerable resources in health information technology (HIT). These technologies indeed have proven to optimize patient care, prevent medical errors, increase the efficiency of care and reduce unnecessary costs [1-5]. Despite these benefits, HIT use in daily healthcare practice has likewise revealed unanticipated– so-called *unintended consequences*. The plethora of studies, showing the extent and importance of unintended consequences, for the most relate to *physician's* usage of electronic health records and computerized provider order entry systems in relation to their *ease of use* [6-11]. Herewith these studies neglect two important aspects related to usage of HIT: HIT usage is not solely related to ease of use, HIT needs to be placed within a, often complex, healthcare system setting (1). A growing segment of HIT is eHealth and eHealth services used by both physicians ánd patients (2). If these eHealth services are to become fully effective, a more complete understanding of the influence of human factors on eHealth's integral usage within the healthcare system is needed, including patient factors possibly influencing the impact of eHealth.

First, many of the unintended consequences flow from *interactions* between the introduced HIT, physical and technical infrastructures of the healthcare organization and the often highly complex healthcare environments [12-20]. They concern issues regarding workflows, communication, cognitive aspects, and an organization's culture and social interactions [12-20]. Within the field of HIT, these aspects are researched within the domain of Human Factors Engineering (HFE). HFE is defined as 'the scientific discipline concerned with the understanding of interactions among humans, 'healthcare' professionals or patients', and other elements of a system and the profession that applies theories, principles and methods to HIT design in order to optimize user well-being and overall system performance' [21-22]. HFE thus has specific benefits applied to healthcare and HIT, such as efficiency improvement in care processes and improved patient outcomes [23].

Secondly, eHealth services have been available to patients for more than a decade [24]. Over time, eHealth services have become emerging tools for supporting patients to directly engage in their health, through stimulating health behavior changes and self-management of their disease [24-25]. This is especially interesting for chronically ill patients, since a health engaged lifestyle can reduce the burden of their chronic disease [25]. HFE aims to ensure that eHealth services are developed that meet the intended health needs, prevent designs that are susceptible to misuse, identify usability issues, minimize input error and enhance safety. Previous research within the field of patient-centered eHealth services shows that HFE approaches are nearly always adopted in the design and development of these HIT interventions [21]. Furthermore, insights on human factors that influence the acceptance,

usability and implementation of patient-centered eHealth services have grown [26-30]. However, evidence on how human factors, such as patient characteristics, mediate the use and *impact* of these eHealth services on patient behavior changes, self-efficacy and health related outcomes is scarce [21, 25]. From 2006 onwards several studies and reports have examined the impact of eHealth solutions [31-33]. These studies address the impact of eHealth on the economics of healthcare systems, the possible improvements of quality and safety of healthcare and how eHealth affects low income countries [31-33]. The impact of eHealth on health related outcomes at patient level are seldom addressed. A meta-analysis of evidence-based research on the impact of patient- centered eHealth interventions on patient behavior changes, self-efficacy and health related outcomes, in relation to human factors issues influencing, these outcomes is needed to explore how these interventions can become maximally effective in healthcare and to drive the further development of these innovations [24].

This survey paper summarizes the overarching themes as emerging from the literature of the last two years on the impact of patient-centered eHealth solutions on patient behavior changes, self-efficacy and health related outcomes and mediating human factors and discusses them within the overall context of unintended consequences of HIT. This is of importance since it enables researchers to pinpoint human factors issues influencing the effectiveness of patient-centered eHealth. This knowledge provides insights in how to discover ways for developing better tailored eHealth solutions and maximizing their benefits. We focus on patient-centered eHealth requiring communication and collaboration with healthcare professionals and healthcare organizations as a means of achieving better patient outcomes [34]. The survey paper concludes with recommendations on research questions to be addressed within the field of human factors in relation to impact studies of patient eHealth interventions on behavior change, self-efficacy and health related outcomes.

2. Methods

We searched PUBMED for studies reporting on patient-centered eHealth applications. We performed two searches. For the first search we combined MeSH term 'patients' with keywords 'patient' or 'patients' in title or abstract, keyword 'ehealth' in title or abstract or all fields, keyword 'factors' in title or abstract and limited our search to papers in English published in 2014 and 2015. For the second search we combined MeSH term 'patients' with keywords 'patient' or 'patients' in title or abstract, keyword 'eHealth' in title or abstract or all fields, keyword 'impact' in title or abstract and limited our search to papers in English published in 2014 and 2015. Together the searches resulted in a total of 350 potentially relevant papers. Results from both searches were deduplicated afterwards. Based on the

titles and abstracts the first author screened all papers for relevancy. To assess inter-rater reliability, all included and excluded papers were examined by the first and second author. Any disagreements or difficult cases were discussed amongst the two authors until consensus was reached. Papers were included if they reported on an eHealth application targeted at patients ánd presented the effects of this application on patient care from a patient's perspective. Since we wanted to learn more on the *impact* of eHealth on patient outcomes and how human factors mediated the impact, we excluded papers that reported on a general status update of eHealth usage, the potential of eHealth, technical issues related to eHealth, eHealth implementation, acceptance or ethical aspects of eHealth usage or if the paper reported on a mobile (mHealth) application. Reviews, commentaries, letters and conference abstracts were excluded. This resulted in the rejection of 330 papers and left 20 full papers for full examination. Full text versions of 2 of the 20 papers were not found and 8 papers were excluded after reading the full text version. This resulted in the inclusion of 10 papers for final data-analysis.

The first phase of the data processing involved an analysis of the studies' research design and the reported impact of the eHealth intervention. The results sections of the papers were analyzed and the impact of the eHealth intervention per paper was categorized using the following categorization: a positive effect of intervention on defined outcomes (+), a neutral effect, meaning no differences (overtime) in effects of intervention on defined outcomes compared to non-users (+/-) and a negative effect of the intervention on at least one of the defined outcomes (-). In the second phase of the data processing we analyzed if the study methods included a formal human factor framework to frame the study results. If not, we analyzed the discussion section of the paper in search for details on how human factors could have influenced the impact of the eHealth intervention on defined outcomes. The Systems Engineering Initiative for Patient Safety (SEIPS 2.0) model [35] was used as a guidance framework to identify the reported human factors possibly impacting the effectiveness of an eHealth intervention. We used a bottom-up analysis to identify human factors that corresponded with SEIPS 2.0 elements, respectively: persons(s) and tasks (system elements) and physical, cognitive, social and behavioral processes (process elements). Human factors within a specific SEIPS element were clustered among recurrent themes: patient characteristics, perceived social support and patient provider interaction.

3. Results

3.1 General characteristics of included studies

Of the 10 included studies, 7 studies involved a randomized controlled trial (RCT). Six of these RCT's reported a positive impact of the eHealth service on (one of) the outcomes: patient

behavior change, self-efficacy or health related outcomes. A post-implementation study and quasi experimental study reported a positive impact on the eHealth service on these outcomes well. In 1 RCT and in 1 pre/post implementation study, the eHealth service did not or only partially improve (one of) the defined outcomes. None of the 10 studies reported a negative impact of the eHealth service. Table 1 provides an overview of all 10 papers.

3.2 Human factors and possible influence on impact of eHealth intervention

Nine of the 10 papers did not use a formal approach to frame and analyze human factor issues; proof on the human factor issues mediating the impact of patient-centered eHealth thus was not made evident in these papers. The remaining one study hypothesized that the human factors self-efficacy and social support would mediate patients' health outcomes and reported a positive impact of these human factors. Table 2 provides an overview of the human factors and their possible influence on impact of the eHealth intervention. Human factors that were most often discussed as possibly mediating the eHealth's impact on defined outcomes are: patients' characteristics, such as social- & cultural background and gender, patients' self-efficacy and cognitions (1) perceived social support (2) and the (type of) interaction between patients and their provider, including individual feedback from provider to patient (3).

First, in a study by Safran Naimark et. al. [41] a web-based app providing tools for monitoring while encouraging (healthy) diet and physical activity proved to be successful in promoting a healthy lifestyle among participants. App users significantly increased the quality of their diet and their weekly duration of physical activity, and lost more weight than the control group not exposed to the tool. Sixty-four percent of the app users were well-educated Caucasian females. In another study by Sepah et. al. [45] active promotion and use of an internet-based lifestyle intervention led to significant reductions of body weight in diabetes patients. The socio-economic status of patients was equally spread, eighty-three percent of the participants were female and more than half of the participants had an ethnicity referred to as 'white' in the paper. In both studies these patient characteristics might have influenced the intervention's impact, since this female participant group might be concerned with their health in general regardless of the specific intervention.

Regarding self-efficacy, a study by Borosund et.al. [38] compared the effect of a web-based illness self-management support system, Internet-based patient provider communication service and usual care among breast cancer patients on symptom distress, anxiety, depression, (primary outcomes), and self-efficacy (secondary outcome). Patients offered the web-based self-management system reported significantly lower symptom distress, anxiety and depression, while patients offered the Internet-based communication service only reported significant lower depression scores compared with the usual care group. Though

no significant differences in self-efficacy were found among the study groups, a tendency towards increased self-efficacy of patients offered the self-management support system was seen. Gomez-Zuniga et. al. [44] assessed whether a web-based program aimed at raising awareness of the importance and promotion of physical activity in managing diabetes led to changes in blood sugar levels and insulin use of diabetes patients and whether these changes were related to patients own perceptions of self-efficacy and social support. Those patients who reduced their blood glucose levels after performing the physical exercise the least were those with lower self-efficacy and lower perceived social support.

Perceived social support was also studied by Allam et. al. [36]. They analyzed the effect of a web-based intervention including social support features and gamification on physical activity, healthcare utilization, medication overuse and knowledge on rheumatoid arthritis of patients suffering from this condition. The major features of the social support concerned a forum and a chat room for exchanging experiences and information with other patients and healthcare providers. Game features introduced a competition-like environment where patients' actions were rewarded. Patients having access both to the social support and gaming features of the intervention gained more empowerment, increased their physical activity and decreased their use of healthcare utilization and medication overuse over time.

On (type of) interactions between patient and provider, a study was performed involving Chronic Obstructive Pulmonary Disease (COPD) patients using a self-management tool offering them personalized advice by the service helpline based on their daily recorded symptoms and pulse oximetry measurements. The study indicated that the tool not only heightened their awareness of their condition but likewise raised their confidence to make self-management decisions [43]. Some patients however avoided using the tool because it reminded them of their disease at times they did not experience any severe symptoms. These patients discontinued using the tool unless the need arose when their symptoms worsened. Most patients became sufficiently confident in their self-management that they did not need their healthcare professionals' opinion. In a study by Ralston et. al., patients suffering from uncontrolled essential hypertension who, in addition to usual care, were offered a home blood pressure monitor in combination with online communication with their pharmacists, were more likely to have standard blood pressure levels than patients offered a home blood pressure monitor only [40]. The online communication supported patients and their pharmacist in monitoring of an action plan concerning a patient's lifestyle goals and medication regime. These results indicate that a blended care model, combining online care management, including online feedback from providers to patients, with self-monitoring of symptoms by patients can be more successful than self-monitoring on its own. Another study assessed the feasibility, acceptability and impact of a patient portal supporting shared decision making by parents of children with asthma and their children's caregivers on asthma

Table 1: *English papers published in 2014-2015 on patient-centered eHealth applications and their impact on patient care, ranked by study design.*

Study design	eHealth intervention Patient group	Reported impact	Ref #
RCT	Oneself: information website with online social support and experimental gamification features *Rheumatoid Arthritis patients*	+ Patients having access both to social support and gaming features gained more empowerment, increased physical activity and decreased use of healthcare utilization and medication overuse over time	[36]
	ESRA-C: web-based program for self-monitoring of symptoms and Quality of Life, self-care education and customized coaching on how to report to physicians *Oncology patients*	+ Intervention group had a decrease in their level of distress	[37]
	WebChoice: web-based illness management support system *Oncology patients with breast cancer*	+ Intervention group reported significantly lower symptoms of distress, anxiety and depression. +/- No significant differences were found among study groups regarding self-efficacy	[38]
	MyAsthma: I linked patient portal supporting shared decision making for pediatric asthma *Family of asthma patients in pediatric care*	+ Both parents and the pediatric asthma patients missed fewer days from work and school respectively + Parents reported use of portal improved their ability to manage their children's asthma condition	[39]
	Home blood pressure monitoring with and without secure web-based pharmacist messaging and phone visits *Patients with hypertension*	+ Patients offered a home blood pressure monitor in combination with online communication with their pharmacists had more standard blood pressure levels then patients offered solely a home blood pressure monitor	[40]
	eBalance: web-based app to promote healthy lifestyle *N.A.*	+ Intervention group significantly increased the quality of their diet, their weekly duration of physical activity and had more reduction in weight than control group	[41]
	Module to guide sick-listed employees to return to work *Patients with mental disorders*	+ 9 months after baseline significantly more participants of the intervention group achieved remission	[42]
Pre-post study	Light Touch service: self-management intervention *COPD patients*	+ Users of the service indicated higher awareness of their condition and increase in confidence to make self-managed decisions +/- Patients avoided use of service, because it reminded them on their condition even when not experiencing severe symptoms	[43]

Study design	eHealth intervention Patient group	Reported impact	Ref #
Post study	Big Blue Test: raise awareness of physical activity *Diabetes Mellitus (type I and II) patients*	+ Patients with higher self-efficacy and access to social support reduced their blood glucose level after exercise best	[44]
Quasi experi-mental study	Prevent: Internet-based diabetes prevention program *Diabetes Mellitus patients*	+ Intervention group showed significantly higher reduction of weight than control group and achieved a long-term weight maintenance effect even after the effective intervention ended	[45]

Table 2. ***Human Factors discussed and their possible influence on impact of eHealth intervention***

SEIPS 2.0 elements Work system processes	Reported Human Factor	Possible influence on impact of eHealth intervention	Ref #
Person(s) physical	*Patient characteristics gender*	Patients' gender might influence their willingness to participate in the study (within the none RCT's)	[41]
Person(s) cognitive	*Patient characteristics cognitions*	Patients' awareness, knowledge and judgement of available methods for dealing with health issues might influence their health behavior change	[42]
	Patient characteristics self-efficacy	Patients' extent or strength of one's belief in one's own ability to complete tasks and reach goals might influence their health behavior change	[38], [44]
Person(s) social	*Patient characteristics socio- cultural, educational background*	Patients' background might influence participation within the study as well as perception and experience of technology and content of the intervention depending on their health- & computer literacy level	[37], 45]
	Perceived social support by patient	Patients' access to social support (as part of intervention or by informal caregiver) might positively influence their engagement with the intervention	[36], [38], [44],
Tasks behavioral	*Patient/provider interaction (individual feedback from provider)*	Bi-directional provider patient communication was part of the intervention and might enhance patients' engagement with intervention positively.	[39], 40], [43]

control, healthcare utilization and days missed from school (children) or work (parents) [39]. Parents reported that use of the portal improved their communication with their children's clinicians, awareness of the importance of ongoing attention to their children's treatment and their ability to manage their children's asthma. Both parents and their children missed fewer days from work and school respectively.

4. Discussion

Evidence-based research on the impact of patient-centered eHealth on patient behavior changes, self-efficacy and health related outcomes is emerging, though few randomized controlled trials have yet been performed. Whereas formal HFE frameworks are applied within the interaction design of patient-centered eHealth, often before implementation of the intervention, a formal approach on human factors mediating the use and effects of these eHealth interventions is scarcely adopted in outcome studies on patient-centered eHealth. Consequently, potential unintended consequences related to human factors mediating the impact of patient-centered eHealth are hard to identify. As a first step, this survey provided insight in several human factors potentially influencing use and impact of patient-centered eHealth interventions, by using the SEIPS 2.0 model as a guidance framework to identify reported human factors via a bottom-up analysis of the discussion section of the eHealth papers.

First, patients may differ in the degree to which they want to be involved in technology-based health intervention programs to support behavior change and self-efficacy, with female, higher educated patients and patients with better clinical conditions being more likely to seek this kind of involvement. In the study by Safran Naimarak [41], the key parameter for success was the frequency of app use, and being a woman likewise predicted success. The sample comprised predominantly adult, well educated, white females. The intended effect of the program by Berry [37] was likewise modified by frequency of its use which was mediated by personal demographics and clinical characteristics. Working cancer patients, patients who had more than high school education and radiation oncology patients voluntarily used the web-based program more than other patients. These patients might have had a better clinical condition, more likely to know how to use a computer or understand health-related information as provided by the program.

Interestingly, the web portal of Fiks [39] was widely used by both suburban white families and urban African American families regardless of socioeconomic status and the internet-based lifestyle intervention of Sepah [45] by a socioeconomically diverse population of people. Whether these eHealth interventions attained similar results regarding impact on patient

care in these diverse groups is yet unclear. Overall these findings show that evidence on demographic differences mediating the impact of patient-centered eHealth interventions is scarce. The ability of patients to benefit from eHealth interventions may be constrained by their limited education, clinical condition, and digital or health literacy. Digital literacy refers to a patient's skills to and knowledge needed for productive interaction with HIT. Health literacy refers to a patient's ability to not only locate but also understand, contextualize and interpret health information. eHealth interventions that fail to consider requirements they impose on a user' abilities could lead to unintended consequences like under- or improper use, misinterpretation of health information or advice provided. Understanding the demographic determinants mediating use and impact of patient-centered eHealth services is thus needed for designing effective eHealth interventions. The questions here are whether and to what extent these factors influence patients' ability to use eHealth tools and what design considerations are important when creating eHealth tools for certain targeted patient populations differing in these characteristics.

A similar plea can be made for understanding the psychological determinants of a self-behavior change process as these can clearly impact behavior changes achieved by patients. Three of these psychological determinants are a patient's self-efficacy, cognitions and social support. Perceived self-efficacy refers to a person's confidence in his or her abilities to perform required actions and achieve desired results. In a healthcare context, perceived self-efficacy concerns a patient's confidence in his abilities to change certain unhealthy behavior patterns or appropriately self-manage his disease. Cognitions refer to a person's mental processes like reasoning by which he acquires certain knowledge. In a healthcare context, cognitions could concern a patient's awareness, knowledge and judgement of available methods for dealing with his health issues. Two studies indeed showed that a patient's perceived self-efficacy level can guide behavior changes concerning diet intake and physical activity [36, 44] and one that patients' cognitions on how to handle daily- work issues given their impairments guided them to return to their work [42]. Some patients may however not be able to take an active role in changing their health-related behaviors due to low a self-efficacy state that does not encourage them to use eHealth aiming at health behavior changes by the eHealth intervention itself. Theory-driven eHealth interventions, mastery experiences and continuous monitoring of behavior changes seemed to motivate users and encourage these changes in the studies of [36, 40, 44]. The question here is how and to what extent eHealth interventions, preferably theory-driven, can contribute to raising self-efficacy as perceived by these patients.

Along with self-efficacy and cognitions, perceived social support can be a very important psychological variable in promoting behavior changes as these changes are encouraged through interaction and support of relevant persons in one's environment. Allam et. al.

[36] indicate that the social support features of their web-based intervention might have increased patients motivation to return to the website, eventually improving their sense of empowerment in dealing with their rheumatoid arthritis. Sharing their experiences and knowledge online with other patients and healthcare professionals even substituted for the need to use real healthcare services. eHealth interventions aiming at health behavior changes that fail to consider the role of social support in facilitating healthy behavior could lead to unintended consequences like unmotivated patients, attrition of users potentially leading to earlier onset or worsening of disease symptoms. Greater elucidation of the details of the relationship between social support structures provided by eHealth interventions and health behavior changes is yet needed to apply knowledge for designing effective patient-centered eHealth interventions. The question here not only is which social support structures work, but also how to integrate those in eHealth interventions so as to enhance patient users 'motivation to change their (unhealthy) behavior patterns and maintain healthy behaviors.

Another method for enhancing users' motivation to change unhealthy or risky behavior may be gamification of eHealth interventions. Gamifying eHealth interventions may not only engage users, increase and continue their participation and motivation but even empower them in handling their health issues. The study of Allam et. al. [36] indeed proved positive effects of a game-based approach in the direction on patients' health-related behavior and outcomes. These authors suggest that patients' participation in a competition-like environment where their actions were rewarded may have increased their motivation and confidence in acquiring and processing the disease related information provided by the eHealth tool. This could eventually have empowered these patients in dealing with their disease. The question here is which gaming mechanisms would affect engagement and empowerment of users in eHealth interventions aimed at self-management of health issues and how.

5. Limitations

We solely included studies that reported on the impact of patient-centered eHealth interventions on patient care. Studies reporting on the implementation or acceptance of patient-centered eHealth were excluded from this meta-analysis whereas in these studies, the mediating influence of human factors on study outcomes is often considered.

Current trends in eHealth are patient-centered mHealth applications, using mobile communications like smartphones for patient health services and patient information. We excluded impact studies of mHealth applications on patient care from the current meta-analysis of the literature but will include these studies in a follow-up meta-analysis.

6. Conclusion

While the amount of patient-centered eHealth interventions is increasing, many questions remain as to what extent and how human factors mediate their effectiveness within the healthcare system and impact on patient health related outcomes. In the search for evidence-based research on the impact of patient-centered eHealth on patient behavior changes, self-efficacy and health related outcomes, only ten studies were included of which the majority reported positive results on (one of these) outcomes. As with any HIT, positive effects of eHealth interventions may however be accompanied by unintended consequences like underuse or misuse. Particularly since most patient-centered eHealth interventions significantly change the role and responsibilities of the patient in dealing with his disease. Most patients and their relatives are interested in gaining greater access to and are ready to embrace eHealth solutions, but others may not be sufficiently motivated, empowered or experience difficulties in using eHealth tools. Future research should incorporate a formal theory on human factors to study how human factors influence the effectiveness of these interventions. The resulting insights can be used to better tailor the content and design of eHealth solutions to different patient user profiles, so as to enhance their impact on patient behavior changes, self-efficacy and health related outcomes.

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