Self-Tracking Technologies Adoption and Utilization: A Literature Analysis

Completed Research Paper

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Abstract

Academic research on Quantified Self (QS) has grown rapidly in recent years in the field of Information Systems. QS intertwines studies on personal ICT, technology adoption, self-monitoring, mobile health, and wearable. However, there is currently no research that synthesizes all these ramifications to reveal the different theories and factors that have been most used to explore this phenomenon. This research presents a literature review and analysis of 75 articles focused on the adoption and utilization different types of QS technologies. The findings indicate a monolithic view on QS, which is commonly examined with the technological lens, thus neglecting also the health and social domains. In addition, future research should diversify the theories and methodological approaches used to study QS.

Keywords

Quantified-self, Personal ICT, m-health, adoption, literature review, research agenda.

Introduction

In recent years, the strong adoption of technologies in the health sector has offered new possibilities to track physiological parameters and daily activities. In particular personal technologies such as self-tracking tools (STT) enable people to manage chronic disease and individual well-being (Swan 2013; Majmudar et al. 2015). Nowadays, several STT technologies are available on the market to track oneself. For instance, mobile applications help manage different diseases such as diabetes, obesity and asthma. STT tools provide lots of opportunities for the healthcare sector, especially by generating data points to be collected and analysed. Moving citizens to self-tracking technologies is an important issue for the healthcare sector in regard to reducing health spending (Rich and Miah 2017).

While the adoption of QS technologies is growing and more academic research is conducted on that research topic (Ruckenstein and Schüll 2017), a good synthesis of the literature is still needed. This research aims at addressing that gap by providing a literature review. The scope of the review examines STT adoption from a multidisciplinary point of view that includes research published in areas such as Information Systems (IS), healthcare and sociology as recommended by De Moya and Pallud (De Moya and Pallud 2017). This study also highlights the methodologies and theoretical frameworks have been used to study self-monitoring technologies at the individual level in recent years. It helps to characterize the development of this research stream and to situate the current state of the art of the field. Specifically, we pose the following questions:

1. What are theoretical and methodological approaches commonly used to investigate the adoption and usage of STT?

2. What are the main factors influencing adoption and usage of STT?

The following section introduces each self-monitoring technology that was examined in the literature review. Then we introduce methodology implemented to collect and analyse the 75 articles. Next, the results of the analysis are presented, discussed and synthesized. We conclude with a summary and recommendations for future research directions.

Self-tracking technologies

This research focuses on the adoption and use of two types of self-tracking technology: mobile health applications and wearable.

Mobile Health and Mobile Health Apps

Mobile health (Mhealth) is at the intersection between electronic health and smartphone technology (Adibi 2015). Mhealth enables data collection with sensors that are either integrated into the mobile technology or connected to the mobile via wireless or wired connections. Data are then manipulated with smartphone applications and transmitted to third parties thanks to cloud infrastructure. Technically, the sensors used by smartphones are the same as those in a smartwatch or an activity bracelet. The smartphone equipped with a tracking application is able to measure the physical parameters of an individual.

Mobile health tracking app is part of m-health, defined by the Global Observatory for e-health of the World Health Organization (WHO) as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants and other wireless devices" (WHO Global Observatory for eHealth and World Health Organization 2011). M-health tracking app generally includes well-being and fitness apps, which track steps and calories, lifestyle information such as sleep, stress management.

Wearable

Wearable technology refers to clothing or accessories produced or improved with electronics. It's an intelligent portable system or “Smart wearable system” (Chan et al. 2012), which consist of sensors for capturing data, storing and transmitting data on the cloud, either standalone or via a smartphone (Weber 2015). They can be used externally to the body, either attached as an accessory or embedded in clothes (Raskovic et al. 2004). There are two categories of wearable material. The first is portable technology allowing people to use the device unobtrusively (Barth 2013). The second category is intelligent textiles, integrating technology into the fabric itself (Page 2015). The primary purpose of these tools is to measure and/or react to stimuli of the environment (Van Langenhove et al. 2012).

Vital parameters that can be evaluated by wearables are electromyogram, electroencephalogram, activity, mobility, breathing, glucose level, oxygen saturation, temperature, and skin galvanic response (Chan et al. 2012). Fitness tracker and smartwatch represent two kinds of wearable widely owned by individuals.

Fitness tracker is a worn wrist bracelet that tracks fitness activities (steps, calories) and users’ health in real time (Yang et al. 2016). They are also known as activity tracker, wearable fitness trackers, wearable fitness technology, smart wristbands or smart bracelets. The primary purpose of these devices is a collection of data that a user can analyse on different devices (e.g., laptop computer or smartphone). The presentation of information is very limited (e.g., pulse or time) and smart wristbands do not offer the possibility to install apps (Chuah et al. 2016).

Smartwatch is a kind of fitness tracker with extended functionalities such as alert notifications (Gay and Leijdekkers 2011). Its size is larger than smart wristbands and often even larger than most traditional watches. “The face of a smartwatch is usually a touchscreen. An operating and app ecosystem allows users to install various apps. It’s a mini device that is worn like a traditional watch and allows for the installation and use of applications“ (Yang et al. 2016, p.277).

In addition to fitness trackers and smartwatch, the following terms were used to perform the literature analysis:

- Healthcare wearable: tracker used in a healthcare aim (diabetes, electrocardiogram, symbiotic system) also known as personal health device, wearable biomedical sensors, self-tracking technology for health fitness and well-being, Sensor-based Global Health Technologies, wearable technology in healthcare, Wearable Devices Based Pervasive Wellbeing Monitoring, Smart healthcare fabric.
- General wearable: in this category is included wearable technology that does not mention any detail on the device, Wearable Ubiquitous Monitoring Device, body-worn sensor system, smart wearable device, self-tracking device.

Research Methodology

Our review methodology follows the information systems tradition to discern patterns in the development of the field (Hoehle et al. 2012). We limit our review to research papers published in the last 10 years because self-tracking have been popular since Quantified-Self movement in 2007 (De Moya and Pallud 2017). The main databases used in academia and management sciences were used: Business Source Premier, Google Scholar, IEEEXplore, Science Direct, and Web of Science. A keyword search was conducted in these different databases in order to identify relevant papers. The search strategy included keywords such as adoption, appropriation, acceptance, perception, continuance, engage, attitude as well as self-tracking devices such as activity tracking devices, fitness tracker, physical activity tracking, healthcare device, mhealth, wristband, wearable.

We limited the search to peer review articles and excluded editorials, books and magazine articles. To cross-check and confirm the relevance of the results, the articles' abstracts were reviewed. Articles that did not focus on the adoption and use of STT were excluded from the study. The search yielded in 75 peer-reviewed research publications. In order to guide the analysis of the research literature the following questions were posed:

- What is the research approach (empirical, non-empirical)?
- What was the research method used?
- What major theories were used to study the adoption and usage of self-tracking devices?
- What factors influencing adoption and usage of self-tracking devices were identified?

In order to answer these questions, we coded each article using the classification offered by Alavi and Carlson (Alavi and Carlson 1992). A data matrix, generated from this coding, helps visualize the similarities and differences between the various research articles (Miles et al. 1984) (An excel file containing this matrix and bibliographic references can be downloaded in www.box.net, please use STTresearch@gmail.com as username and review1 as the password).

Findings

Research type and methods

Regarding the research approach used to study STT, five articles were classified as non-empirical work and correspond to conceptual articles or literature reviews. The only literature review identified is in the medical field and aims to reference body-worn sensor system preferences from patient's and clinician's perspective (Bergmann and McGregor 2011). Conceptual papers help to understand STT with different explanatory theories, such as the Technology Acceptance Model (TAM) (Ajani 2014) or Maslow's theory (Thielke et al. 2012; Gimhae 2013).

Qualitative Research

Ten articles have examined STT using qualitative methodologies specially to gain a better understanding of QS adoption. The focus group methodology (3 articles) that facilitates the expression of several points of view was implemented with smartphone owners in order to identify the motivations behind the adoption of health apps (Peng et al. 2016). This study also highlights some barriers to adoption such as low awareness of health apps, lack of app literacy and cost. (Canhoto and Arp 2017) used a series of focus

groups to examine adoption and sustainability of health and fitness wearable. Goal orientation emerges as a factor of adoption whilst portability appears as a factor of sustainability.

Semi-structured interviews were also used to collect user experience and it represents the most commonly used qualitative methods (7 articles). For example, Sjöklint et al. (Sjöklint, et al. 2015) examined users' experience with fitness trackers. They showed that tracker is used more as a refocus tool to self-explore health than a commitment device to change behaviour. They conclude that the adoption process refers to a self-exploration phase. Another example is Neil et al. (Neill et al. 2016) paper study who interviewed stakeholders from six organizations and revealed factors that influence the adoption of wearable in an organisational context. Cost is one of the main barriers to the adoption of wearable in organizations. None articles presented a case study methodology, which can be explained by the fact that STT adoption is mainly examined at the individual level. Although grounded theory could be relevant for exploring new behaviours related to QS, none article applied this methodology.

Last, some research focuses on STT data such as Meyer et al. (Meyer et al. 2016) who used self-tracking data along with qualitative interviews with patients. They conducted a longitudinal exploration of tracker activity usage by patients with myocardial infarction. For instance, this approach allowed them to observe usage interruptions. Huberty et al. (Huberty et al. 2015) also combined data related to time (of when the tool was carried) and user interviews.

Quantitative Research

The main quantitative methodology implemented to study STT adoption is the survey methodology: in total, 48 quantitative studies test a research model with a survey to explain STT usage. For example, Hong et al. (Hong et al. 2017) developed a research model predicting customer's continuous intention to use a smartwatch, and gathered data using a survey to test their model. STT usage continuance is determined by consumer innovativeness and moderated by hedonic value and utilitarian value to wear a smartwatch.

Herrmann and Kim (Herrmann and Kim 2017) employed Theory of Planned Behaviour (TPB) to explain usage of fitness app over 5 months. Their finding shows that subjective norms have no impact on perceived behaviour control, app usage, effectiveness, and usefulness. Our last example is Alley et al. (Alley et al. 2016), implemented a questionnaire to measure individuals' interest in using an activity tracker, how they use them and the consequences of their physical activity level. Overall, tracker usage is related to the need and motivation to do physical activity. People who already have a good level of activity or who do not want to do sports, do not see any interest in the use of activity trackers.

Theories Used to Study the Adoption of STT

Three studies have applied Theory of Reasoned Action (TRA) or its extension the Theory of Planned Behaviour (TPB) to study consumer behaviour towards STT. Two studies have combined these models with specific theoretical constructions from the STT literature. Jia and Kim (Jia and Kim 2015) offer a TPB-based model that includes attitude, subjective norm, control of perceived behaviour and the influence of social media. They combine this model with the theory of Diffusion Of Innovation (DOI). Their model is designed to understand the adoption of smart watches such as the Apple watch. Moran et al. (2013) built a model to compare the adoption of ubiquitous surveillance devices between the British and Japanese. They use TPB combined with attitude towards technology, and attitude towards applications as an antecedent to attitude towards behaviour and behavioural intention to use the technology.

The Technology Adoption Model (TAM) was created to explain why individuals accept a technology in the workplace (Davis et al. 1989). 18 papers extended the TAM-based model to explain STT adoption by accounting for technological and behavioural aspects. For example, Chuah et al. (Chuah et al. 2016) added a new variable, namely visibility defined as "a person's beliefs about the extent to which smart watches are noticed by others (Fisher & Price, 1992)" (Chuah et al., 2016, p.278) to explain the adoption of smart watches. Several years after TAM, a new model emerged in IS literature, named Unified Theory of Acceptance and Use of Technology (UTAUT). This model build by Venkatesh et al. (Venkatesh et al. 2003) is a unified view of eight models extensively used in IS, comprising TPB and TAM. The evaluation of their model explains more variance than others. Ten papers used UTAUT and UTAUT2 to explain STT. For example, Pfeiffer et al. (Pfeiffer et al. 2016) added a reflexive dimension to the UTAUT, which consists in

trust, perceived aesthetics, and personal innovativeness.. This addition is supposed to better reflect the human-machine interaction.

Social cognitive theory (SCT) was introduced by Bandura (Bandura 1986) and anticipate that individuals become motivated and guide their actions through their beliefs and self-efficacy. SCT is used in conjunction with other models to explain the behaviour to maintain a physical activity or to encourage changing behaviour. Three papers relying on the SCT want to explain how STT leads to self-efficacy. For example, Ehlers and Huberty (Ehlers and Huberty 2014) incorporate both SCT and UTAUT to examine user preferences for mobile Physical Activity app. Self-regulation emerged as a variable that improves physical activity. The literature shows 22 papers which do not belong to any of the categories commonly used in IS literature, but they appear in other fields such as UX modelling (Shin and Biocca 2016) or don't rest on a specific model. The literature on STT is transversal so it includes many motivational, psychological or persuasion factors to explain adoption and utilization (Shih et al. 2015) and the self-efficacy of technologies in behavioural change (Park et al. 2015). Beyond the adoption of technologies, researchers also question the usefulness of STT for health and well-being management, which are the top promises made by STT manufacturers. For instance, Shin and Biocca (2016) used the Transtheoretical Model (TTM) and the Expectation Confirmation Theory (ECT) to explain pre and post-adoption. The transtheoretical model is generally used to explain why an individual changes her/his behaviour.

Theoretical constructs	**Article counts**	**Associated adoption theories**
Perceived usefulness	32	TAM
Ease of use	23	TAM
Subjective norms	14	TRA
Behavioural intention	18	TRA
Attitude towards actor behaviour	11	TRA
Performance Expectancy	11	UTAUT
Facilitating Conditions	10	UTAUT
Effort Expectancy	9	UTAUT
Perceived behavioural control	8	TPB
Enjoyment	7	
Perception of Privacy	7	
Perception of Trust	7	
Attitude Toward Technology	7	TAM
Hedonic Motivation	7	UTAUT2
Price Value	7	UTAUT2
Personal Innovativeness	6	
self-efficacy	6	SCT
Compatibility	5	DOI
Aesthetically Design	5	
Comfortable	5	DOI
Anxiety	4	SCT
Perceived Value	3	
Habit	3	UTAUT2

Table 1. Constructs found in the self-tracking adoption literature limited to 3 article counts

The variables used for the study of adoption and use with different technologies

Table 1 summarizes the constructs found in the self-tracking adoption literature. We restricted this table to the most cited variables up to three citations (due to paper size constraints) because several constructs were only found one or two times in the literature. This volume corresponds to 121 variables by a total of 144 variable.

Ease of use, utility and subjective norms are the most common factors in the literature. Attitude towards technology and behavioural intention to use are widely used variables. This underlines the importance of the TAM theory in the analysis of the acceptance of STT.

Healthcare wearable		**Fitness Tracker**		**Smartwatch**		**Mobile App**	
Social norm	4	Perceived usefulness	13	Perceived usefulness	5	Ease of use	9
Ease of use	4	Ease of use	8	Hedonic Motivation	4	Perceived usefulness	9
Perceived usefulness	4	Comfortable	5	Aesthetically Design	3	Subjective norms	9
Anxiety	3	Attitude towards tech	5	Ease of use	3	Effort Expectancy	8
Attitude towards tech	3	Aesthetically Design	4	Price Value	3	Facilitating Conditions	7
Comfortable	2	Social norm	3	Compatibility	2	Performance Expectancy	7
Enjoyment	2	Behavioural intention	3	Continuance	2	Perceived behavioural control	6
Perception of Privacy	2	Facilitating Conditions	3	Brand Familiarity	2	Behavioural intention	5
Perception of Trust	2	Price Value	3	Enjoyment	2	Perception of Privacy	4
Personal Innovativeness	2	Neglect	2	Mobility	2	Self-efficacy	4
Perceived Privacy Risk	2	Barriers to use	2	Personal Innovativeness	2	Attitude towards tech	4
Self-Congruence	2	Incentive	2	Social norm	2	Hedonic Motivation	4
Behavioural intention	2	Observational learning	2	Attitude towards tech	2	Enjoyment	3
Satisfaction	1	Perception of Trust	2	Behavioural intention	2	Perceived Physical Condition	3
Perceived Severity	1	Self-Expression Motivated	2	Performance Expectancy	2	Perception of Trust	3

Table 2. Most frequent constructs used to study STT technologies Constructs found in the self-tracking adoption literature limited to the 15 first factors.

This literature review led to identify the different adoption factors with regard to different technologies. The findings reveal significant differences across technology type. While the adoption of healthcare wearable could be related to the social norm, people who adopt smartwatches will rely on hedonic motivations such as the aesthetics of the device or brand image. Price represents a factor of adoption for Fitness Tracker and smartwatch as these items can cost several hundred euros. Comfort, as well as the price and desire to have an aesthetic object, are also found in studies on fitness trackers. Social influence appears to be a factor that can determine adoption and effective usage. Indeed, these devices are linked to health, and there may be strong social pressure to take control of one's health through this type of tool.

For healthcare wearables such as diabetes monitoring tools, privacy considerations and trust appear in the factors that influence adoption. The type of data collected by healthcare wearables (such as glycaemia) is much more sensitive to users than data collected by a fitness tracker (such as steps). Therefore, healthcare wearables must be trustworthy, both in terms of data security and in terms of precision of measurement. Table 2 summarizes the most common variables used for each technology.

Discussion on Future Directions

The literature review allowed us to identify the main factors used in the adoption studies as well as the different theories applied. These disparities highlight the importance of considering a more generic model on which to base the research in the field. This model could therefore serve as a foundation and be extended to other technologies by adding specific factors. Quantified Self could be used as a generic (or umbrella) term on which to base the development of the because its definition is relatively wide but remains precise:

“The philosophy behind the QS movement is that by using quantifiable data, which can be collected relatively easily through readily available technology, one can significantly improve the understanding of one’s health and gain deeper insights into different approaches to improving health” (Kim 2014).

Beyond the different technologies, personality traits also show their importance. For example, the need to analyse STT data may also involve a kind of curiosity and specific personality traits. In addition, the perception of one's state of health as a person's concern for one’s health, the ability to engage in a process of self-determination or the feeling that the individual believes that his or her health is his or her own responsibility are also found in the literature. Other approaches use variables related to data security, the risk of loss of privacy and exploitation of its data by third parties, or financial risk when purchasing such equipment, which may be very expensive and may not meet the buyer's expectations. For now, only one study uses the “big five personality traits” as variables that influences adoption (Prayoga and Abraham 2016). The five personality traits could be used as moderators: neurosis, openness, consciousness, extroversion and pleasant character (McCrae and Costa 2003). Thus, we recommend taking particular attention on different personality traits as moderator variable in future adoption model.

At the conceptual level, we have found that some theories are still under-exploited and yet seem promising. The following models are some examples that could be used in future research:

The Elaboration Likelihood Model is a persuasion model (Cacioppo and Petty 1984) based on a dual change process. The model suggests two ways to achieve persuasion. The first is the central path of motivation, which reflects a strong commitment, carefully considering the messages received. This path leads to sustainable change. The second path uses a peripheral message. The attitude formed by the central pathway is stronger than that formed by the peripheral pathway. This model could predict how STT can persuade individuals to change their behaviour.

Health Belief Model addresses individual differences in beliefs and attitudes to explain health-related behaviours (Janz and Becker 1984). It is based on the attributes of perceived susceptibility, perceived severity, perceived benefits, perceived barriers and triggers for action. The latter variable refers to the ability of STT to alert the user to perform appropriate behaviour. Therefore, encouraging action could be an important factor in explaining the continued attitude towards use.

Expectation Confirmation Theory has been used by IS researchers to test post-adoption behaviours. It explains product satisfaction related to product expectation and perceived performance (Bhattacherjee 2001). Failure to confirm user expectations has an impact on long-term adoption.

Privacy Calculus theory refers to the issue of privacy protection (Li et al. 2016). The decision-making process for adopting STT is a calculation between the benefit provided by the product and the risk of invading a person's privacy through the use of the product.

These different theories highlight that for a deeper understanding of STT, we should combine IS adoption theories, persuasive and motivational theories, as well as privacy and personality traits. The small number of qualitative articles also shows the need to keep exploring the QS phenomenon, especially with intensive methodologies that allow long-term observation. For instance, diary studies, ethnography or longitudinal studies could offer rich findings. It would also be useful to develop a sociotechnical approach to monitoring practices to understand how the relationships between the machine, the user and his or her environment are intertwined (Rapp and Tirabeni 2018). This approach could benefit from a study in organizations that have adopted STT tools.

Another shortcoming is the lack of studies on STT taking the relationship between the body and health, the relationship between data and privacy and the feeling of being increasingly monitored by the state and private third parties. It would be interesting to highlight the particularities of a country and examine their impact on the use of the STT.

Conclusion

This article provides an overview of the literature on the adoption of self-tracking tools. To better understand the state of research in this area, a comprehensive review of 75 peer-reviewed articles was conducted.

Our conclusions support the need for research in this area, whether in terms of methodology or in terms of theory. In particular, we point out the difficulties that appear in the study of STT due to the multitudes of technologies. This problem should encourage researchers to converge towards a unified theory that could be expressed under the umbrella of Quantified-Self. We also advise researchers to explore other models to enrich knowledge in terms of adoption, motivation, and persuasive technology. Finally, our research also identifies a gap in the use of moderator variables. In particular, personality traits have not yet been sufficiently studied.

This article also faces certain limitations. Although our literature review is comprehensive and covers a number of different research areas, it is possible that some articles have been overlooked. This remark is especially noteworthy as we are on a trendy subject and a lot of research is regularly published. It is therefore important to regularly update this study. In addition, the analysis of the 75 articles is limited to four main questions. Future studies should examine other issues, such as how STT choices are influenced by age, gender, or difference between culture.

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