Asia Pacific Journal of Information Systems
Vol. 28 No. 2 (June 2018), 114-132

ISSN 2288-5404 (Print) / ISSN 2288-6818 (Online)
https://doi.org/10.14329/apjis.2018.28.2.114

Sustaining the Use of Quantified-Self Technology : A Theoretical Extension and Empirical Test

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A B S T R A C T

Quantified-self technologies (QSTs) provide functions for users to collect, track, and monitor personal data for self-reflection and acquisition of self-knowledge. Although QSTs require prolonged use to reap the attendant benefits, many users stop using their devices or tracking within weeks or months. To address this issue, this study seeks to determine ways to sustain the use of QSTs. Combining motivational affordance theory with technology continuance theory, this study develops a theoretical model that accounts for an individual's continued intention to use a QST. Within the proposed model, unique QST affordances were identified as antecedents of individual motivation in relation to technology continuance, and their different roles in stimulating hedonic, utilitarian, and eudaimonic motivations were examined. The model was tested using data collected from 180 QST users. Results demonstrate that although utilitarian and eudaimonic motivations are complementary forces in determining continuance intention, hedonic motivation loses its predictive power in favor of eudaimonic motivation. Tracking, visualizing, and sharing affordances play different roles in elevating user motivations. The sharing affordance does not influence utilitarian and eudaimonic motivations, but it positively influences hedonic motivation. This research contributes to the literature on technology continuance by shifting scholarly attention from hedonic–utilitarian duality to eudaimonic motivation, characterized by meaning, self-growth, and pursuit of excellence.

Keywords: Quantified Self, Motivation, Technology Continuance, Affordance

Ⅰ. Introduction

As sensing technologies and mobile and wearable digital devices connected to the Internet have become more and more embedded in our daily lives (Shin, 2017), quantified-self technologies (QSTs) are becoming increasingly prevalent. QSTs are defined as "those technologies that help people collect personally relevant information for the purpose of self-reflection and gaining self-knowledge" (Li et al., 2010) (p. 558). QSTs designed for gaining self-knowledge and insights into oneself include iWatch, Galaxy Gear,

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Nike+ FuelBand, Garmin VivoFit, and Jawbone UP (Chamberlain et al., 2015). By providing users with information about themselves, the use of QSTs increases self-control and promotes positive behavioral changes (Li et al., 2011).

Despite the increasing popularity of QSTs, it has been reported that around half of users discontinue using their QSTs several months after their purchase (Coorevits and Coenen, 2016; Epstein et al., 2016b; Patel et al., 2015). Because QSTs require prolonged use to reap the attendant benefits, continued engagement with the technology is important (Fritz et al., 2014). Consequently, the question of how to sustain people's use of QSTs requires empirical investigation.

Researchers argue that the provision of certain affordances that stimulate user motivation is key to facilitating continued engagement with technology (Jung et al., 2010; Zhang, 2008a). However, there is a lack of understanding of the specific affordances engendered by QSTs and how they elevate user motivation regarding technology continuance. In addition, although the use of QSTs require users to perceive eudaimonic value, such as self-fulfilling and self-improvement, (Deterding, 2014; Suh and Cheung, 2017), prior research has overlooked the eudaimonic aspect of user motivation. Instead, researchers have mainly focused on utilitarian factors (i.e., the efficiency, convenience, and functionality of the technology) or hedonic factors (i.e., feelings of pleasure, enjoyment, fun, and sensuality) (Gu et al., 2010; Kim, 2016). Although some researchers have suggested examining the role of eudaimonic motivation in relation to technology continuance (Deterding, 2014; Suh and Cheung, 2017), the dynamics of eudaimonic motivation alongside hedonic and utilitarian motivations in explaining user continuance intention is lacking in the existing literature.

To fill these gaps in understanding, this study draws on motivational affordance theory (Zhang, 2008a) against the backdrop of technology continuance theory (Van der Heijden, 2004) to develop a theoretical model that explains users' continuance intention regarding the use of QSTs. Specifically, this study addresses the following questions:

1. *What are the unique QST affordances that stimulate user motivation to use the technology?*
2. *How do different types of user motivation (hedonic, utilitarian, and eudaimonic) play different roles in determining users' continuance intention?*

The study contributes to the IS literature by identifying unique QST affordances and explaining their role in stimulating user motivation regarding QST use. Additionally, by introducing the concept of eudaimonic motivation, this study extends scholarly attention from the hedonic-utilitarian duality to a more nuanced user motivation in relation to eudaimonic aspects of technology use. By doing so, the study seeks to provide both a theoretical explanation and an empirical justification of how to sustain the use of QSTs. In practical term, the study has the potential to offer design guidelines for industry to promote sustainable user engagement with QSTs.

Ⅱ. Theoretical Background

2.1. QST Affordances as Motivational Drivers

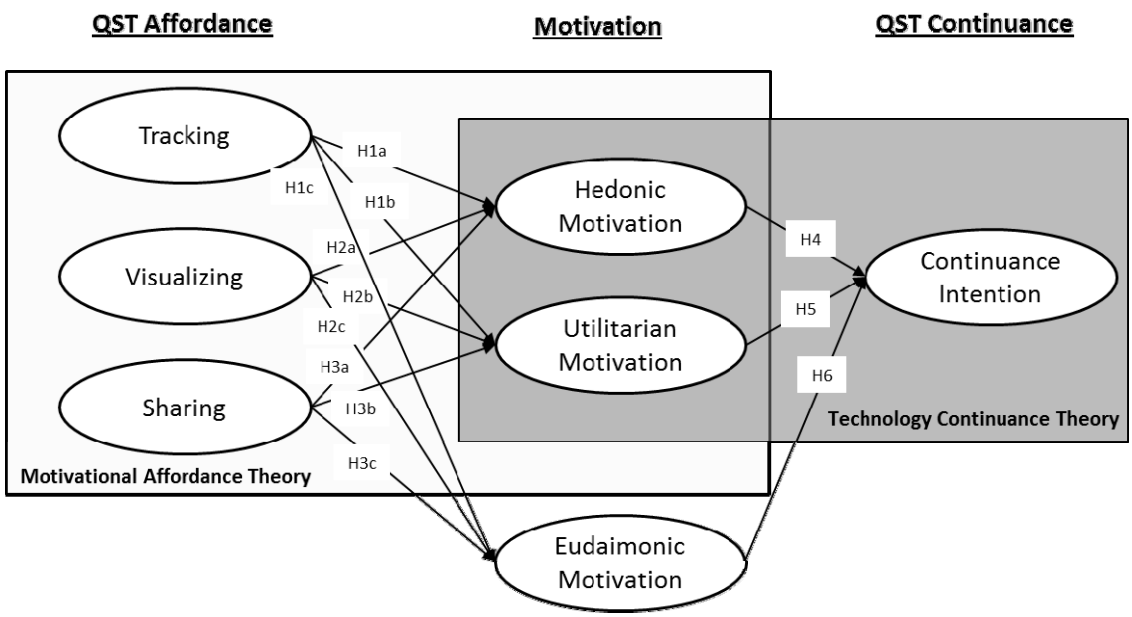
An affordance refers to the relationship between a user and the technological artifacts in a specific situation (Leonardi, 2011). Thus, from a combination of actual and perceived properties of a technological features, users can determine how the technology will be used. Given that users perceive different tech-

nological capabilities, there might be a gap between what users expect and what a technology can actually do (Suh et al., 2017). Therefore, the usability of a technology is determined by the user perception of what a technology affords (Leonardi, 2014). Following the notion of affordance theory (Kaptelinin and Nardi, 2012; Norman, 1988), a QST affordance in this study is defined as the extent to which a user perceives that there is a fit between his or her goals and the relevant actions to be performed through the use of the technology.

Researchers argue that users' perceived affordances need to be assessed when seeking to determine whether a technology has the appropriate functions for these users to perform their desired action (McGrenere and Ho, 2000). Employing the concept of affordance, Zhang (2008) developed motivational affordance theory, which suggests that perceived affordances elevate user motivation for technology usage (Zhang, 2008a). According to Zhang (2008), motivational affordances are the "properties of an object that determine whether and how it can support one's motivational needs" (p. 145). Therefore, technologies that promote user motivation should be designed in such a way that the technological features engender proper affordances to fulfill users' needs and goals.

Motivational affordance theory (Zhang, 2008) suggests that successfully conveying the affordances of a technology is key to facilitating user motivation for technology continuance (McGrenere and Ho, 2000; Van Vugt et al., 2006). As affordances do not exist without the user's perception of the technological features, the creation of desirable affordances and the level of user awareness of these affordances are critical to stimulating user motivation (Grgecic et al., 2015). The central tenet of motivational affordance theory is that user motivation can be elevated by a user's perceived affordance.

In order to develop a theoretical model that



<Figure 1> Research Model

explains a QST user's continuance intention, this study combines motivational affordance theory (Zhang, 2008b) and technology continuance theory (Van der Heijden, 2004). While motivational affordance theory focuses on the relationship between technological affordance and user motivation, technology continuance theory focuses on the relationship between motivation and continuance intention. These two theoretical approaches have been developed in parallel, and researchers have thus far failed to integrate them. This paper thus develops a comprehensive research model that combines technological affordances, user motivation, and continuance intention in order to build a theoretical logic to link the affordance and technology continuance literature. <Figure 1> shows how this study combines the two theories to build the research model for QST continuance.

2.2. QST Affordances and User Motivation

Research has found that the gap between what users expected and what a QST could actually do resulted in confusing and disappointing experiences (Kim et al., 2016a). Therefore, if a user perceives a greater affordance from the use of a QST, this means that there is a fit between his or her goals and the technological capabilities of the QST. Drawing on the literature review in interaction design and system development research (Epstein et al., 2013; Epstein et al., 2016b; Lomborg and Frandsen, 2016), three key QST affordances have been identified: tracking, visualizing, and sharing. <Table 1> summarizes the QST system's features and the affordances engendered by these features.

The concept of a "tracking affordance" refers to the extent to which a user perceives that the QST affords an opportunity to collect and monitor in-

<Table 1> Summary of QST System Features and Related Affordances

QST Affordance	System Features	References
Tracking	Software sensors: applications and functions that aid the user in capturing activities, emotions, or experiences. Hardware sensors: devices that automatically collect personal and contextual information (e.g., accelerometers, heart rate sensors, and light sensors, thermometers, etc.)	(Rivera-Pelayo et al., 2012) (Kim et al., 2016a)
	Functions to collect information from different devices for data fusion and from different groups of people for data comparison.	(Rooksby et al., 2014; Rivera-Pelayo et al., 2012)
	Functions to provide feedback about users' activities and performance (e.g., points, levels, badges, and trophies)	(Fritz et al., 2014; Jia et al., 2016)
Visualizing	Functions to plot users' activities (e.g., histogram, point ranges, and scatter plots with trendlines)	(Epstein et al., 2016a; Lomborg and Frandsen, 2016)
	Functions to highlight users' performance with visual framing (e.g., positive vs. negative framing)	(Kim et al., 2016b)
	Information dashboard, including summary panel, history chart, hourly trends panel	(Kim et al., 2016b)
Sharing	Functions to share users' activity data, progress report, and achievement through social networking applications (e.g., Facebook, Twitter), and communities on fitness tracking website.	(Fritz et al., 2014; Munson et al., 2015)

formation about his or her activities and performances. A greater tracking affordance can be perceived by users when a QST enables them to collect precise information through which they can receive prompt feedback on their activities (Rapp and Cena, 2015). The acquisition of immediate feedback leads to dynamic interactivity between the user and the technology, leading to fun and enjoyment derived from the use of the technology (Chun et al., 2012). Therefore, self-tracking has been considered a means through which to stimulate users' hedonic motivation (Lomborg and Frandsen, 2016). Tracking also enables users to become more aware of their own behavior and their status because it enables users to reflect on themselves. Given that tracking enables users to perform their target activities and achieve their instrumental purposes (e.g., losing or maintaining weight), the tracking affordance stimulates the user's utilitarian motivation (Jun et al., 2015). Finally, tracking enables users to set a goal limit (e.g., a calorie burn and intake) with reference to the tracked information. By analyzing their performance outcomes, users can determine the goals and actions that would be appropriate to pursue and experience self-improvement (Suh and Cheung, 2017). Researchers have found that the tracking affordance engendered by a QST increases its users' self-awareness because they can compare their current state to the ideal state or goal (Kim et al., 2016b). As feedback gained from self-monitoring facilitates the process from self-awareness to goal-setting, the tracking affordance stimulates users' needs to pursue excellence and self-growth (Mekler and Hornbæk, 2016). Accordingly, the following hypotheses are formulated:

H1a: Tracking is positively associated with hedonic motivation for QST usage.

H1b: Tracking is positively associated with utilitarian motivation for QST usage.

H1c: Tracking is positively associated with eudaimonic motivation for QST usage.

QSTs visualize users' performance outcomes, ranging from an overall summary of their activity over a time period to more fine-grained visualizations (e.g., the routes that users run). A greater visualizing affordance can be achieved when a QST provides visual feedback, not only on changes and stability in users' activities, but also on their achievement (Lomborg and Frandsen, 2016). Because QSTs visualize users' activities and performance using diverse visual elements, such as charts, tables, and icons, users can reflect on their bodily conditions and practices. Visual stimulation and the aesthetics of a technology lead to hedonic enjoyment (Cyr et al., 2006). Conversely, users can quickly analyze their factual data through graphical elements, meaning that the technology provides instrumental utility as a tool for monitoring users' activities. Finally, visualizing helps users to frame their activity as achievement (Epstein et al., 2016b), satisfying their needs for competence and self-growth, and stimulating their eudemonic motivation. Therefore, this study proposes the following hypotheses to examine the roles played by different QST affordances in influencing user motivation:

H2a: Visualizing is positively associated with hedonic motivation for QST usage.

H2b: Visualizing is positively associated with utilitarian motivation for QST usage.

H2c: Visualizing is positively associated with eudaimonic motivation for QST usage.

The sharing affordance refers to the extent to which

a QST enables users to share their performances with others. QSTs embed features for sharing users' personal data with others for networking, comparing, and commenting, allowing users to establish connections and communicate with other users through the use of technology (Baek et al., 2013; Bakardjieva, 2005). Greater sharing affordance can be perceived when QSTs enable users to share their personal data through online communities or social networking tools (Consolvo et al., 2009; Fritz et al., 2014; Munson et al., 2015). Researchers have found that a QST's capacity to offer social features is a powerful motivator (Epstein et al., 2015; Toscos et al., 2006). A sharing affordance engenders hedonic enjoyment because people feel fun and pleasure when they share their personal experiences, including their goals, achievement, and activities on social networks (Ryan et al., 2006). Sharing personal data with others helps users to understand their status and to identify potential partners for their activity (Epstein et al., 2013), eliciting a utilitarian value. From a eudaimonic standpoint, the sharing of findings goes beyond simply having a personal connection: experiences of relatedness have been considered an important aspect of eudaimonic well-being, which gives people a sense of meaning in their lives. Accordingly, the sharing affordance stimulates users' eudemonic motivation.

H3a: Sharing is positively associated with hedonic motivation for QST usage.

H3b: Sharing is positively associated with utilitarian motivation for QST usage.

H3c: Sharing is positively associated with eudaimonic motivation for QST usage.

2.3. User Motivation and QST Continuance

Research on user motivation in technology continuance can be thought of as falling into two traditions, one of which is the hedonic tradition, where the focus is on the emotional benefits derived from using the technology, such as feelings of pleasure, fun, enjoyment, and sensuality (Kim, 2016; Park, 2003). The other is the utilitarian tradition, where the focus is on the instrumental benefits of technology use, such as convenience, usefulness, and functionality (Lou and Koh, 2017; Van der Heijden, 2004). This hedonic vs. pragmatic duality has been widely adopted as a promising approach to understanding technology continuance, but it has ignored the eudaimonic aspect that psychologists have offered for understanding the intrinsic motivation of human behavior (Waterman et al., 2008). According to eudaimonic identity theory (Waterman, 2011), people have an intrinsic motivation to strive toward excellence or perfection, the achievement of which is worth pursuing in life in terms of recognition of the "true self." The idea of eudaimonia (seeking meaning, self-growth, and pursuit of excellence) as a motivation for technology continuance complements the idea that individuals use a technology as a means of developing their identity (Ma and Agarwal, 2007) and as a way to experience meaningful engagement with the technology (Mekler and Hornbæk, 2016; Suh et al., 2017). Therefore, this study extends the view of user motivation by adding eudaimonic motivation as a predictor of technology continuance.

H4: Hedonic motivation is positively associated with the continuance intention to use a QST.

H5: Utilitarian motivation is positively associated with the continuance intention to use a QST.

H6: Eudaimonic motivation is positively associated with the continuance intention to use a QST.

Ⅲ. Methods

3.1. Data Collection

To test the proposed model, this study adopts a survey method, whereby empirical data were collected from users of a QST. Data were collected from QST users in an online community where community members share their experiences of using QST apps and tools. An online survey was created by a survey company for data collection; an email invitation including the survey link was sent to the community members. To minimize the confounding effects caused by different purposes of QST use, the survey covered only QST users who had used their QST (including devices or apps) for healthcare and fitness. The survey participants were asked to write down the name of the QST they used most and to keep it in mind while answering the survey questions. The survey lasted until 200 questionnaires were collected. After removing 20 responses that contained unanswered items, 180 responses were used for the final analysis. Respondents' demographic information is summarized in <Table 2>. To test for possible nonresponse bias, the study compared early and late respondents and no statistical differences were found between the two groups. Thus, the problem of nonresponse bias was not detected in the study.

3.2. Measurement

The survey participants responded to the questionnaire items by indicating their agreement on a seven-point Likert scale that ranged from "strongly disagree" to "strongly agree." Items assessing tracking, visualizing, and sharing were developed from

<Table 2> Demographic Characteristics of the Respondents

Item	Category	Frequency	Ratio (%)
Gender	Male	123	68.33%
	Female	57	31.67%
Age	20 - 29	20	11.11%
	30 - 39	64	35.56%
	40 - 49	62	34.44%
	> = 50	34	18.89%
Education	High school	12	6.67%
	College (2 year)	7	3.89%
	College (4 year)	145	80.56%
	Graduate	4	2.22%
	Above	12	6.67%
Occupation	Student	37	20.56%
	Office worker	102	56.67%
	Self-employer	32	17.78%
	Others	9	5.00%
QST device used	iWatch	41	22.78%
	Galaxy Gear	65	36.11%
	Mi Band	37	20.56%
	Fitbit	29	16.11%
	Others	8	4.44%

the conceptualizations of QST affordances (Lomborg and Frandsen, 2016; Rooksby et al., 2014). Items assessing utilitarian motivation and continuance intention were adopted from Van der Heijden (2004). Lastly, items measuring hedonic and eudaimonic motivations were adopted from Mekler and Hornaek (2016). <Appendix> provides a complete list of the questionnaire items used in this study.

Ⅳ. Results

The proposed model explores the interplay QST users' evaluation of the technological features, their motivations, and continuance intention. Accordingly, to test the model, using the structural equation modeling method (Anderson and Gerbing, 1988), this study examined the statistical significance of the relationships between the proposed variables. Partial least squares (PLS) regression was used for the data analysis. PLS is appropriate for the early stages of theory development (Barclay et al., 1995) because it imposes minimal restrictions on data distribution (Chin et al., 2003). SmartPLS 3.0 was used to estimate both the measurement and structural models.

4.1. Measurement Model

Before testing the measurement model, the skewness, kurtosis, and normalized multivariate kurtosis were examined to ensure data normality (Bollen and Lennox, 1991). The results showed that no deviation from normality existed. In addition, we tested the internal validity and convergent and discriminant validities of the measurement model. As shown in <Table 3>, Cronbach's alphas and item loadings were all above 0.7, meeting the recommended value of 0.7 (Hair et al., 2006). One item for eudaimonic motivation (EDU1) was removed from the final analysis due to its low loading (Hair et al., 2006). The average variance extracted (AVE) from each construct was higher than the recommended value of 0.5 (Fornell and Bookstein, 1982), as shown in <Table 3>. The square root of the AVE for each construct is represented in the diagonals of the table. The value of each construct was higher than its correlations with all other constructs, suggesting sufficient discriminant validity (see <Table 4>). Furthermore, given that all of the correlation coefficients were lower than the recommended threshold of 0.7 (Hair et al., 2006), serious multicollinearity did not exist in the data. Additionally, the index of variance inflation factor (VIF) was checked to examine whether multicollinearity posed problems in the dataset. The VIF scores ranged from 1.543 to 2.777, which are well below the recommended threshold value of 10 (Harter et al., 2002). Accordingly, the results indicate that multicollinearity was not likely to be a serious issue in this study.

Finally, Harman's one-factor analysis was conducted to check whether a single factor would emerge from the factor analysis or whether one general factor would account for the majority of the covariance in the research variables (Podsakoff and Organ, 1986). To examine if common method bias (CMB) posed a threat to the quality of the dataset, all the measurements were subjected to a principal component analysis. It was found that no single factor dominated the variance explained in the data.

4.2. Structural Model

To verify the hypotheses, the structural model was assessed by examining the explanatory power of the constructs and the statistical significance of the posited paths. As shown in <Figure 1>, the results

showed that tracking was positively associated with utilitarian (b = 0.275, $p < 0.001$) and eudaimonic (b = 0.358, $p < 0.001$) motivations, whereas tracking had no influence on hedonic motivation. The results also show that visualizing was positively associated with hedonic (b = 0.344, $p < 0.01$), utilitarian (b = 0.320, $p < 0.01$), and eudaimonic (b = 0.504, $p < 0.001$) motivations. Sharing was found to be positively

<Table 3> Internal Reliability and Convergent Validity of the Measurements

Construct	Item	Factor Loading	Cronbach's alpha	Composite reliability	AVE
Tracking	TRC1 TRC1 TRC1	0.888 0.903 0.887	0.803	0.884	0.717
Visualizing	VIS1 VIS2 VIS3	0.853 0.858 0.857	0.820	0.893	0.735
Sharing	SHA1 SHA2 SHA3	0.850 0.876 0.846	0.818	0.892	0.733
Hedonic Motivation	HED1 HED2 HED3 HED4	0.803 0.878 0.833 0.724	0.790	0.877	0.663
Utilitarian Motivation	UTI1 UTI2 UTI3	0.831 0.832 0.849	0.743	0.854	0.704
Eudaimonic Motivation	EUD2 EUD3 EUD4 EDU5	0.780 0.760 0.818 0.772	0.820	0.874	0.581
Continuance Intention	CON1 CON2 CON3	0.890 0.902 0.886	0.873	0.922	0.797

Note: AVE: average variance extracted

<Table 4> Descriptive Analysis and Discriminant Validity of the Measurement

Construct	Mean(DS)	1	2	3	4	5	6
TRC	**0.847**						
VIS	0.435	**0.857**					
SHA	0.575	0.629	**0.856**				
HEO	0.524	0.473	0.556	**0.814**			
UTI	0.361	0.641	0.616	0.507	**0.839**		
EUD	0.656	0.514	0.601	0.699	0.505	**0.762**	
CON	0.476	0.655	0.635	0.521	0.669	0.552	**0.893**

associated with hedonic motivation (b = 0.285, $p < 0.01$), but it had no influence on utilitarian and eudaimonic motivations. Accordingly, Hypotheses 1b, 1c, 2a, 2b, 2c, and 3a were supported, whereas Hypotheses 1a, 3b, and 3c were not supported. Notwithstanding, the results show that utilitarian (b = 0.475, $p < 0.001$) and eudaimonic (b = 0.338, $p < 0.001$) motivations positively influenced continuance intention, explaining 68.7% of the variance in continuance intention, whereas hedonic motivation had no influence on continuance intention. Accordingly, Hypotheses 5 and 6 were supported, while Hypothesis 4 was not supported.

Ⅴ. Discussion

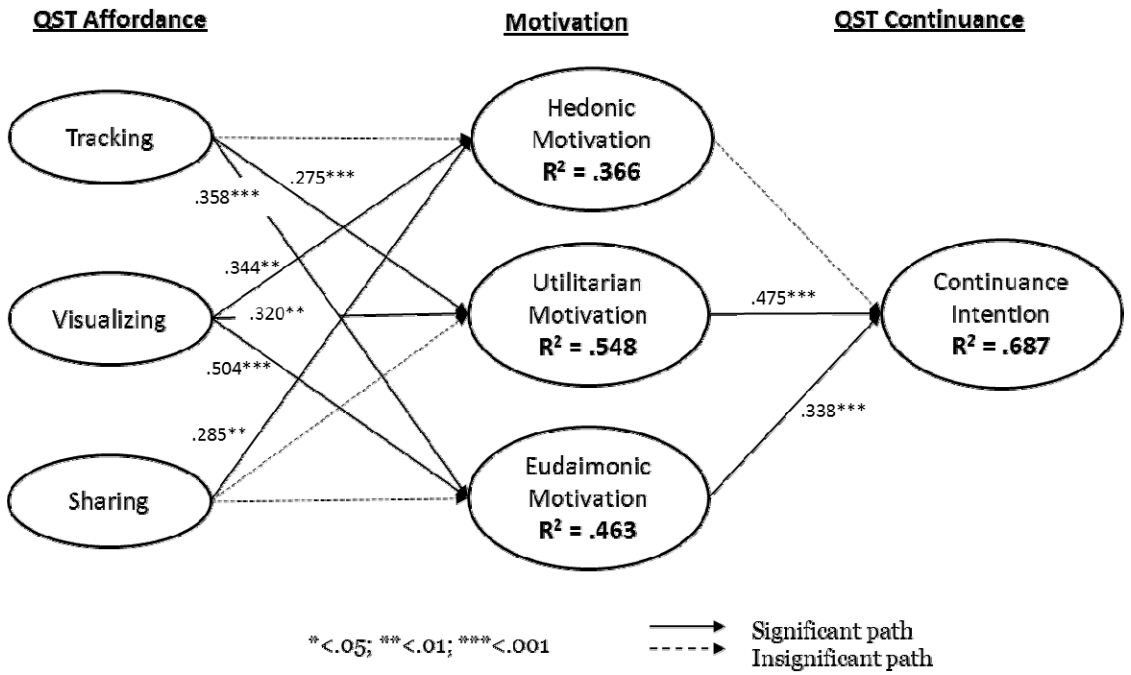
The main purpose of this study was to understand how to sustain people's use of their QSTs. This was achieved by identifying three QST affordances (i.e., tracking, visualizing, and sharing) and examining their different roles in elevating different types of user motivation in relation to technology continuance. Furthermore, by conceptualizing eudaimonic motivation as a determinant of a user's continuance intention, the study sought to shift scholarly attention from the conventional hedonic-utilitarian duality to a more nuanced understanding of user motivation.

The study found that QST users' continuance intention was determined by utilitarian and eudaimonic motivations. To contrary to our expectation, hedonic motivation was found to have no significant influence on continuance intention. The post hoc analysis revealed that hedonic motivation had a significant influence on continuance intention (b = 0.204, $p < 0.01$) when eudaimonic motivation was not entered into the regression model (see <Figure 3>); hedonic motivation lost its predictive power in favor of eudaimonic motivation (see <Figure 2>). The result indicates that progress in technology continuance theory can be made by considering eudaimonic motivation as the emerging nature of QST technology in addition to utilitarian and hedonic motivations.

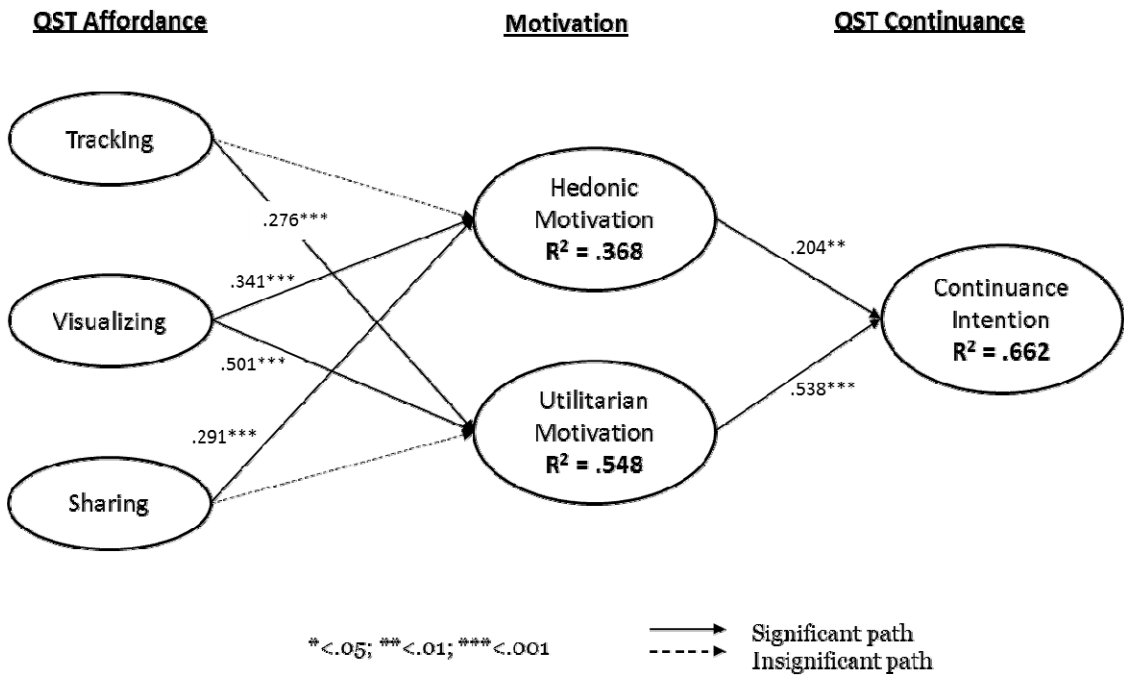
Although utilitarian and hedonic factors have primarily been studied as the foci of technology continuance, eudemonic factors, such as the pursuit of excellence, personal meaning, and self-growth, are now increasingly being regarded as important predictors of continuance. By empirically demonstrating that eudaimonic motivation serves as a reliable theoretical concept for QST continuance, this study complements existing concepts aimed at understanding user motivation in technology continuance.

The study also found that the three QST affordances played different roles in elevating user motivation. As expected, tracking and visualizing affordances significantly increased utilitarian and eudaimonic motivations, accounting for 54.8% and 46.3% of their variances, respectively. The finding indicate that tracking and visualizing affordances are complementary forces that elevate utilitarian and eudaimonic motivations. In particular, it was found that visualizing had the most salient effect on eudaimonic motivation, indicating that the QST functions of the visualization of user activity, progress, and achievement are critical to increasing users' eudaimonic motivation.

It is noteworthy that while the sharing affordance positively influenced hedonic motivation, it had no significant influence on utilitarian and eudaimonic motivations. The results therefore contradict the belief that QST users want to share their personal information to better understand their current status by comparing their performance with others, thus increasing instrumental and eudaimonic benefits.



<Figure 2> Structural Model



<Figure 3> PLS Summary of the Post-hoc Analysis: The Hedonic-Utilitarian Model

Considering that many QSTs provide technical functions that enable users to share their activity data or progress reports with their friends and family through social network applications, the role of the sharing affordance needs to be revisited. Some researchers have pointed out that sharing activity data or progress reports through social networks often resulted in QST users feeling fearful of appearing boastful and of receiving negative replies from their audience (Munson and Consolvo, 2012; Newman et al., 2011). It was found that the sharing of personal information through social networks generally did not motivate users unless their friends also used QSTs or had similar patterns of activity (Fritz et al., 2014). Accordingly, one possible explanation for the non-significant effects of sharing on utilitarian and eudaimonic motivations is that QST users do not have instrumental or meaningful support bases through which they can share their personal information through their connections on social network applications because they do not have similar patterns of activity, or they do not share common interests (Munson et al., 2015).

5.1. Implications for Research

The study provides several key contributions to research. First, it contributes to the creation of theory-based knowledge for designing a QST that better motivates users to continue using the technology. The model, which links unique QST affordances and different types of user motivation (hedonic, utilitarian, and eudaimonic), serves as a theoretical platform to examine, verify, and advance understanding of how to design a QST that can sustain user engagement over time. The findings from this study indicate that user motivation seems to be elevated by both the creation of desirable affordances and the level of user awareness of these affordances. The newly developed scales for QST affordances were empirically validated with sufficient psychometric properties. Our measurements of the QST affordances can be used to assess and quantify how QST users react to technological features so as to determine how to foster desirable affordances that stimulate different types of user motivation. The study found that the tracking, visualizing, and sharing affordances jointly influence user motivation, suggesting that ignoring even one aspect of the three QST affordances may significantly reduce user motivation, which may consequently lead to a decrease in continuance intention. Although the significance or magnitude of each affordance can vary depending on different QST contexts, the study underscores that the unique and distinguished QST affordances we identified in this study are meaningful antecedents of user motivation, which propels people to continue using their QSTs.

Second, the study proposes the concept of eudaimonic motivation as a valid extension of extant technology continuance research. While researchers have called for a more nuanced understanding of user motivation for QST continuance (Gottschalg and Zollo, 2007; Ke et al., 2012), previous research has limited its view to utilitarian and hedonic motivations (Van der Heijden, 2004), overlooking how new technological affordances engendered by QSTs stimulate users' eudaimonic motivation. Unlike other studies that conceptualized user motivation within the hedonic-utilitarian duality, this study took a more nuanced approach to user motivation by adding eudaimonic motivation into the QST continuance model, thereby enriching the understanding of user motivation for technology continuance.

According to a current study (Choe et al., 2014), people use QSTs to improve their physical or mental conditions, to pursue meaning-in-life, and to find

new life experiences. These motivations behind the use of QSTs are characterized by eudaimonia, that is, users pursue meaning-in-life, self-growth, and excellence through the use of technology. Nonetheless, the current technology continuance models in the IS literature do not capture such eudaimonic aspects in user motivation. By showing empirically that eudaimonic motivation serves as a reliable theoretical concept in explaining QST continuance, this study helps researchers to better understand user motivation for technology continuance.

5.2. Implications for Practice

The study has several practical implications. First, the results imply that QST developers should consider enhancing the key QST affordances identified in this study. If users discontinue the use of a QST device or app, system developers may assess users' perceptions of its technological functions and examine whether there is a gap between what users think they can do through the use of the technology and what the technology can actually do. In particular, as demonstrated in this research, given that utilitarian and eudaimonic motivations are elevated by tracking and visualizing affordances, manufacturers may consider enhancing the functionalities for tracking and visualizing; they also need to assess whether users perceive the desired levels of the affordances on the basis of functionalities. The study found that the visualizing affordance had a greater influence than the tracking affordance on both utilitarian and eudaimonic motivations. Therefore, system designers need to devote attention to creating greater levels of visualizing affordances. Prior research suggests that users perceive different levels of the visualizing affordance depending on how the visualization is framed (Kim et al., 2016b). For example, it was found that people are more likely to be motivated by negative framing (emphasizing what the user missed) than positive framing (emphasizing what the user performed) by increasing self-awareness. Therefore, system designers may wish to consider how to leverage framing effects to stimulate user motivation to sustain their engagement.

Second, system designers may revisit design strategies that might have been used to enhance the sharing affordance. Research has suggested that finding the right people or communities with whom QST users can share their data is key to sustaining their engagement with the technology (Fritz et al., 2014). Instead of relying on the general connections within an online social network application, system designers should consider adding functions to support the formation of groups with specific interests or goals so that QST users can easily find relevant and motivating groups of people. A QST system may analyze the user's activities and suggest relevant groups with similar patterns.

5.3. Limitations and Future Research

The study contributes to the QST literature by proposing eudaimonic motivation and its antecedents from the affordance perspective. However, its predictive power and significance for continuance intention would vary depending on the purpose and the context of QST usage. Thus, this study calls call on researchers to examine the proposed model in different QST contexts to ensure its generalizability. Second, this study collected data from a single source and measured all research constructs by assessing respondents' perceptions. Including objective data, such as QST users' actual usage behaviors, will help alleviate concerns regarding CMB and provide valuable insights into how eudaimonic motivation influ-

ences continued technology usage. Finally, the study identified three QST affordances and verified that technological affordances positively influenced users' motivations. Future research may benefit from extending the framework by identifying more comprehensive technological affordances that stimulate user motivations regarding QST usage.

Ⅵ. Acknowledgement

This research was supported by Grant No. CityU 6391221 from the University Grants Committee (UGC) of the Hong Kong SAR.

<References>

[1] Anderson, J. C., and Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*(3), 411-423.

[2] Baek, H., Kim, J. H., and Kim, Y. J. (2013). An Analysis for Deriving New Convergent Service of Mobile Learning: The Case of Social Network Analysis and Association Rule. *Information Systems Review, 15*(3), 1-37.

[3] Bakardjieva, M. (2005). *Internet society: The Internet in everyday life*. Sage.

[4] Barclay, D., Higgins, C., and Thompson, R. (1995). The partial least squares (PLS) approach to causal modeling: Personal computer adoption and use as an illustration. *Technology Studies, 2*, 285-309.

[5] Bollen, K., and Lennox, R. (1991). Conventional wisdom on measurement: A structural equation perspective. *Psychological Bulletin, 110*(2), 305-314.

[6] Chamberlain, A., Poole, E., Munson, S., Danis, C., and Churchill, E. (2015). Moving beyond e-health and the quantified self: the role of CSCW in collaboration, community and practice for technologically-supported proactive health and wellbeing. *Proceedings of the 18th ACM Conference Companion on Computer Supported Cooperative Work & Social Computing*. ACM, 273-276.

[7] Chin, W. W., Marcolin, B. L., and Newsted, P. R. (2003). A partial least squares latent variable modeling approach for measuring interaction effects: Results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study. *Information Systems Research, 14*(2), 189-217.

[8] Choe ,E. K., Lee, N. B., Lee, B., Pratt, W., and Kientz, J. A. (2014). Understanding quantified-selfers' practices in collecting and exploring personal data. *Proceedings of the 32nd annual ACM conference on Human factors in computing systems*. ACM, 1143-1152.

[9] Chun, H., Lee, H., and Kim, D. (2012). The integrated model of smartphone adoption: Hedonic and utilitarian value perceptions of smartphones among Korean college students. *Cyberpsychology, Behavior, and Social Networking, 15*(9), 473-479.

[10] Consolvo, S., Klasnja, P., McDonald, D. W., and Landay, J. A. (2009). Goal-setting considerations for persuasive technologies that encourage physical activity. *Proceedings of the 4th international Conference on Persuasive Technology*. ACM.

[11] Coorevits, L., and Coenen, T. (2016). The rise and fall of wearable fitness trackers. *Annual Meeting of the Academy of Management*. Anaheim, California.

[12] Cyr, D., Head, M., and Ivanov, A. (2006). Design aesthetics leading to m-loyalty in mobile commerce. *Information & Management, 43*(8), 950-963.

[13] Deterding, S. (2014). *Eudaimonic design, or: Six invitations to rethink gamification, Niklas Schrape*. Lüneburg: Meson press 2014. Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2466374

[14] Epstein, D. A., Avrahami, D., and Biehl, J. T. (2016a). Taking 5: Work-breaks, productivity, and opportunities for personal informatics for knowledge workers. *Proceedings of the 2016 CHI Conference on Human*

Factors in Computing Systems. ACM, 673-684.

[15] Epstein, D. A., Borning, A., and Fogarty, J. (2013). Fine-grained sharing of sensed physical activity: a value sensitive approach. *Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing*. ACM, 489-498.

[16] Epstein, D. A., Jacobson, B. H., Bales, E., McDonald, D. W., and Munson, S. A. (2015). From nobody cares to way to go!: A Design Framework for Social Sharing in Personal Informatics. *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*. Canada: ACM, 1622-1636.

[17] Epstein, D. A., Kang, J. H., Pina, L. R., Fogarty, J., and Munson, S. A. (2016b). Reconsidering the device in the drawer: lapses as a design opportunity in personal informatics. *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM, 829-840.

[18] Fornell, C., and Bookstein, F. L. (1982). Two structural equation models: LISREL and PLS applied to consumer exit-voice theory. *Journal of Marketing Research, 19*(4), 440-452.

[19] Fritz, T., Huang, E. M., Murphy, G. C., and Zimmermann, T. (2014). Persuasive technology in the real world: a study of long-term use of activity sensing devices for fitness. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 487-496.

[20] Gottschalg, O., and Zollo, M. (2007). Interest alignment and competitive advantage. *Academy of Management Review, 32*(2), 418-437.

[21] Grgecic, D., Holten, R., and Rosenkranz, C. (2015). The Impact of Functional Affordances and Symbolic Expressions on the Formation of Beliefs. *Journal of the Association for Information Systems, 16*(7), 580-607.

[22] Gu, J.-C., Fan, L., Suh, Y. H., and Lee, S.-C. (2010). Comparing utilitarian and hedonic usefulness to user intention in multipurpose information systems. *Cyberpsychology, Behavior, and Social Networking, 13*(3), 287-297.

[23] Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., and Tatham, R. L. (2006). *Multivariate data analysis*. Pearson Prentice Hall Upper Saddle River, NJ.

[24] Harter, J. K., Schmidt, F. L., and Hayes, T. L. (2002). Business-unit-level relationship between employee satisfaction, employee engagement, and business outcomes: a meta-analysis. *Journal of Applied Psychology, 87*(2), 268-279.

[25] Jia, Y., Xu, B., Karanam, Y., and Voida, S. (2016). Personality-targeted Gamification: A Survey Study on Personality Traits and Motivational Affordances. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 2001-2013.

[26] Jun, J. G., Lee, T. M., and Park, C. (2015). Utilization of Mobile Information and Perceptions of Society : A Comparison of Korea, China, U.S.A and Japan. *Information Systems Review, 17*(3), 19-38.

[27] Jung, J., Schneider, C., and Valacich, J. (2010). Enhancing the motivational affordance of information systems: The effects of real-time performance feedback and goal setting in group collaboration environments. *Management Science, 56*(4), 724-742.

[28] Kaptelinin, V., and Nardi ,B. (2012). Affordances in HCI: toward a mediated action perspective. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 967-976.

[29] Ke, W., Tan, C.-H., Sia, C.-L., and Wei, K.-K. (2012). Inducing intrinsic motivation to explore the enterprise system: The supremacy of organizational levers. *Journal of Management Information Systems, 29*(3), 257-290.

[30] Kim ,Y.-H., Jeon, J. H., Choe, E. K., Lee, B., Kim, K., and Seo, J. (2016b). TimeAware: Leveraging framing effects to enhance personal productivity. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 272-283.

[31] Kim, D.-J., Lee, Y., Rho, S., and Lim, Y.-K. (2016a). Design Opportunities in Three Stages of Relationship Development between Users and Self-Tracking Devices. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM,

699-703.

[32] Kim, K. J. (2016). Round or Square? How Screen Shape Affects Utilitarian and Hedonic Motivations for Smartwatch Adoption. *Cyberpsychology, Behavior, and Social Networking, 19*(12), 733-739.

[33] Leonardi, P. M. (2011). When flexible routines meet flexible technologies: Affordance, constraint, and the imbrication of human and material agencies. *MIS Quarterly, 35*(1), 147-167.

[34] Leonardi, P. M. (2014). Social media, knowledge sharing, and innovation: Toward a theory of communication visibility. *Information Systems Research, 25*(4), 796-816.

[35] Li, I., Dey, A. K., and Forlizzi, J. (2011). Understanding my data, myself: supporting self-reflection with ubicomp technologies. *Proceedings of the 13th international conference on Ubiquitous computing*. ACM, 405-414.

[36] Li, I., Dey, A., and Forlizzi, J. (2010). A stage-based model of personal informatics systems. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 557-566.

[37] Lomborg, S., and Frandsen, K. (2016). Self-tracking as communication. *Information, Communication & Society, 19*(7), 1015-1027.

[38] Lou, L., and Koh, J. (2017). Enhancing Fan Participation in Social Media Based Virtual Brand Communities: The Case of Like, Comment, and Share Activities. *Asia Pacific Journal of Information Systems, 27*(1), 54-76.

[39] Ma, M., and Agarwal, R. (2007). Through a glass darkly: Information technology design, identity verification, and knowledge contribution in online communities. *Information Systems Research, 18*(1), 42-67.

[40] McGrenere, J., and Ho, W. (2000). Affordances: Clarifying and evolving a concept. *Graphics Interface*, 179-186.

[41] Mekler, E. D., and Hornbæk, K. (2016). Momentary Pleasure or Lasting Meaning?: Distinguishing Eudaimonic and Hedonic User Experiences. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 4509-4520.

[42] Munson, S. A., and Consolvo, S. (2012). Exploring goal-setting, rewards, self-monitoring, and sharing to motivate physical activity. *Pervasive computing technologies for healthcare (Pervasive Health), 2012 6th international conference on*. IEEE, 25-32.

[43] Munson, S. A., Krupka, E., Richardson, C., and Resnick, P. (2015). Effects of public commitments and accountability in a technology-supported physical activity intervention. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 1135-1144.

[44] Newman, M. W., Lauterbach, D., Munson, S. A., Resnick, P., and Morris, M. E. (2011). It's not that i don't have problems, i'm just not putting them on facebook: challenges and opportunities in using online social networks for health. *Proceedings of the ACM 2011 conference on Computer supported cooperative work*. ACM, 341-350.

[45] Norman, D. A. (1988). *The psychology of everyday things*. Basic books.

[46] Park, C. (2003). Online Hedonic-Experiential Value in Internet Shopping: Antecedents and Consequences. *Asia Pacific Journal of Information Systems, 13*(4), 73-96.

[47] Patel, M. S., Asch, D. A., and Volpp, K. G. (2015). Wearable devices as facilitators, not drivers, of health behavior change. *JAMA, 313*(5), 459-460.

[48] Podsakoff, P. M., and Organ, D. W. (1986). Self-reports in organizational research: Problems and prospects. *Journal of Management, 12*(4), 531-544.

[49] Rapp, A., and Cena, F. (2015). Affordances for self-tracking wearable devices. *Proceedings of the 2015 ACM International Symposium on Wearable Computers*. ACM, 141-142.

[50] Rivera-Pelayo, V., Zacharias, V., Müller, L., and Braun, S. (2012). Applying quantified self approaches to support reflective learning. *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge*. ACM, 111-114.

[51] Rooksby, J., Rost, M., Morrison, A., and Chalmers,

M. C. (2014). Personal tracking as lived informatics. *Proceedings of the 32nd annual ACM conference on Human factors in computing systems*. Toronto, Canada: ACM, 1163-1172.

[52] Ryan, R. M., Rigby, C. S., and Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion, 30*(4), 344-360.

[53] Shin, D.-H. (2017). Conceptualizing and measuring quality of experience of the internet of things: Exploring how quality is perceived by users. *Information & Management*, http://dx.doi.org/10.1016/j.im.2017.02.006.

[54] Suh, A., and Cheung, C. M. (2017). Beyond Hedonic Enjoyment: Conceptualizing Eudaimonic Motivation for Personal Informatics Technology Usage. *HCI International 2017*. Vancouver, Canada.

[55] Suh, A., Cheung, C. M., Ahuja, M., and Wagner, C. (2017). Gamification in the Workplace: The Central Role of the Aesthetic Experience. *Journal of Management Information Systems, 34*(1), 268-305.

[56] Toscos, T., Faber, A., An, S., and Gandhi, M. P. (2006). Chick clique: persuasive technology to motivate teenage girls to exercise. *CHI'06 extended abstracts on Human factors in computing systems*. ACM, 1873-1878.

[57] Van der Heijden, H. (2004). User acceptance of hedonic information systems. *MIS quarterly, 28*(4), 695-704.

[58] Van Vugt, H. C., Hoorn, J. F., Konijn, E. A., and de Bie Dimitriadou, A. (2006). Affective affordances: improving interface character engagement through interaction. *International Journal of Human-Computer Studies, 64*(9), 874-888.

[59] Waterman, A. S. (2011). Eudaimonic identity theory: Identity as self-discovery. *Handbook of identity theory and research*. Springer, 357-379.

[60] Waterman, A. S., Schwartz, S. J., and Conti, R. (2008). The implications of two conceptions of happiness (hedonic enjoyment and eudaimonia) for the understanding of intrinsic motivation. *Journal of Happiness Studies, 9*(1), 41-79.

[61] Zhang, P. (2008a). Motivational affordances: reasons for ICT design and use. *Communications of the ACM, 51*(11), 145-147.

[62] Zhang, P. (2008b). Technical opinion Motivational affordances: reasons for ICT design and use. *Communications of the ACM, 51*(11), 145-147.

<Appendix> Questionnaire Items

Tracking	
The QST offers me the possibility to: TRA1: track my performance. TRA2: receive informational feedback regarding my activities. TRA3: monitor how I perform to achieve my goals.	Lomborg and Frandsen (2016) Rooksby et al. (2014)
Sharing	
The QST offers me the possibility to SHA1: share my performance with others. SHA2: share the information on my activities with others. SHA3: let other people to know about my achievements.	Lomborg and Frandsen (2016) Rooksby et al. (2014)
Visualizing	
The QST offers me the possibility to VIS1: understand my physical condition and practices visually. VIS2: see my performance with graphical elements. VIS3: have a comprehensive picture of my performance.	Lomborg and Frandsen (2016) Rooksby et al. (2014)
Utilitarian motivation	
UTI1: The use of the QST enables me to decide more quickly and more easily what I need to do for my health than in the past. UTI2: The use of the QST enables me to decide what I need to do for my health than in the past. UTI3: The use of the QST enables me to decide more quickly and more easily how I can improve my health.	Van der Heijden (2004)
Hedonic motivation	
HED1: The use of the QST is enjoyable. HED2: I had fun using the QST. HED3: The use of the QST is pleasurable. HED4: The use of the QST makes me relaxed.	Mekler and Hornbæk (2016)
Eudaimonic motivation	
EUD1: The use of the QST enables me to seek to do what I believe in.* EUD2: The use of the QST enables me to pursue excellence or a personal ideal. EUD3: The use of the QST enables me to improve myself. EUD4: The use of the QST enables me to seek to use the best in myself. EUD5: The use of the QST enables me to develop a skill, learn, or gain insight into something.	Mekler and Hornbæk (2016)
Intention to use	
INT1: I would plan on using the QST in the future. INT2: I intend to continue using the QST in the future. INT3: I expect my use of the QST to continue in the future.	Van der Heijden (2004)

Note: * Removed item

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Submitted: February 9, 2018; 1st Revision: March 16, 2018; Accepted: April 13, 2018