User Affordances in a Mediated Relationship Between Artefact or Tools and the Related Components Within an Activity System

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Abstract

Yang notes that "despite the positive prospects and functionality of wearable devices, little research has been done on user acceptance and behaviours concerning them" (2016:256). Using Engestrom's second generation Activity theory (1983) our study examines wearable fitness devices ability to influence and aid users' behaviour. We did this towards determining the associated user affordances that unfold when users engage with these wearable fitness trackers.

Our focus was to gain an understanding through studying artefacts and tools, how human action is shaped by and inseparable from a mediated connection between artefacts or tools and the linked components within an activity system. Semi-structured interviews were conducted with 8 participants. These were coded and thematically analysed Using Atlas Ti using the lens of Activity Theory, interviews were examined and thematically coded. Several themes were identified, as we will illustrate below.

Keywords: Internet of things, ubiquitous computing, pervasive computing, wearable tech-nology, activity theory

1. Introduction

Wearable devices are a component of the Internet of Things (IoT) that allow communication to occur between various IoT devices, devoid of human interaction, by connecting all devices both actual and virtual in real-time. These Internet enabled devices, which are integrated within the physical world, become part of a constant interchange and sharing of information, aiding in diverse applications such as predictive maintenance, reduced human effort, health and patient monitoring and better data analytics.

As part of the 2030 United Nations Sustainable Development Agenda and the World Economic Forum's Digital Economy and Society System Initiative, the Internet of Things (IoT) has been identified as a key technology with value-generating applications in sustainability, environmental improvement, competitive markets and more sophisticated products as a consequence (Arias, Lueth & Rastogi, 2018).

2. Wearable Devices

Wearable devices are able to accumulate, analyse, share and assimilate data and information with diverse networked devices. These wearable fitness trackers have gained popularity amongst current society (Ericsson. com, 2016). An Ericsson Consumerlab study (2016) involving a quantitative online survey of 2500 users of wearable devices between ages 15-65 across five countries, determined five key findings. One of these identified wearable trackers as the most individualised device with users reporting themselves as feeling "naked" without their device. The same survey identified usage over several categories, results of which report that 67(%) of people made use of their wearable device during exercise, 49(%) while at work or college, 48(%) while shopping, 33(%) during dinner time and 26(%) whilst sleeping in bed.

The aforementioned paper and remark by Yang (2016:256) is reinforced as a vital area of research as Yang mentions Chuah et al. (2016:276) who say that "[al]lthough still in the early stages of diffusion, smart watches represent the most popular type of wearable devices. Yet, little is known about why some people are more likely to adopt smart watches than others." Fritz, Huang, Murphy and Zimmermann (2014) emphasise that these persuasive technologies that collect, track and record user data over time, hold the potential to motivate and influence behaviour and change.

Table 1: From International Data Corporation, Global Wearable's Market, November 2017 (IDC 2017)

Vendor	3Q17 Volumes	3Q17 Market	3Q 2016 Volumes	3Q16 Market	Year to Year
Xiaomi	3.6M	13.7%	3.7M	15.2%	-3.3%
Fitbit	3.6M	13.7%	5.4M	21.9%	-33.0%
Apple	2.7M	10.3%	1.8M	7.3%	52.4%
Huawei	1.6M	6.0%	0.6M	2.5%	156.4%
Garmin	1.3M	4.9%	1.3M	5.4%	-3.3%
Others	13.5M	51.4%	11.7M	47.7%	15.7%
Total	26.3M	100%	24.5M	100%	7.3%

3. Literature Review

We began the review assuming behavioural affordances were offered by smart watches, taking into account the lack of detail that is actively known about the specifics and the extent to which these behaviours can be altered or affected. This review explores these concepts, as well as yet unconsidered benefits. We used article abstracts and reference searches and a number of databases, EBSCOhost, AMC digital library, Academic Research Premier and IEEE Xplore Digital Library, to obtain data (van Staden, 2019). We based our selection on the number of citations, journal type and subject relevance, applying distinct constructs and categories to our search to obtain relevant literature. This served as an independent first phase of the research process, as we were able to identify the most relevant and critical areas of research with respect to the potential affordances that users gain from smart device use.Studies were included if they were written in English between 2014 and 2018 and reported on research findings that clearly related to our own research. Our search yielded 10 308 articles based on keyword entries of which 10 098 were eliminated based on exclusion criteria, reporting on perception and behaviour in virtual reality, haptic visual interaction and motor imagery, design structure matrices, input devices and wearable technology, activity based working in the office, activity recognition systems, embedded RFID's, source code instrumentation, mobile app design, cloud objects, wireless technology, power management, cloud computing servers, Big Data etc. Database and article searches resulted in 210 studies, which we screened for eligibility through reading of article abstracts, illustrated in Table 2.

Using Atlas Ti for data analysis and coding our procedure involved employing predetermined codes and the development of new codes. Initial codes were distilled into sub-codes towards data saturation. As an example, the construct affordances were refined to include types of affordances such as functional and cognitive affordances. Current literature suggests that wearable trackers hold key affordances including motivation, reflection and self-monitoring that facilitate behavioural change methods around personal needs and objectives. An awareness of these variables related to user context, usage and related value, increases our existing knowledge around the topic. Literature clearly suggests that wearable trackers can influence and shape behaviour over time and sustained usage. Literature furthers that these wearable trackers have key affordances such as motivation, reflection and self-monitoring that facilitate behavioural change methods around personal needs and objectives. These findings are illustrated in figures 1.

Table 2: Summary of inclusion and exclusion criteria (Author, 2018)

Number of records through online academic databases and search engines (include. EBSCOhost, AMC digital library, Academic Research Premier and IEEE Xplore Digital Library and Google Scholar) Keywords: behavior, wearable devices, smartwatches, activity trackers, benefits, affordances and fitness trackers.	
Period 2014-2018	10 308
Additional records through other sources eg. references	26
Exclusion criteria	10 098
Screened records	184
Records assessed for eligibility	106
Studies included in Literature Review	54
Full text articles excluded	52

4. Method

Our research formed part of a narrative study that explored current users' relationships with wrist-worn wearable fitness devices to provide an understanding of how device use and interactions relate to personal and social practices (Johnson & Onwuegbuzie, 2004). Data from literature in the form of a content analysis was employed to identify points of discussion in the field. Data saturation was achieved after interviewing four of our eight participants, all interviewed qualitatively. Data was coded and adjusted in accordance to participant responses. Participants at the time we're users of wearable fitness trackers which we identified via peers and target sampling. The snowballing sampling technique was also deployed to engage with participants (van Staden, 2019). Figure 2 illustrates themes obtained from our first phase content analysis.

Key Authors	Adoption factors	Affordances and Barriers	Behaviour and Influence	Challenges	Coaching	Real world context	Strategies for behavior change	Barriers to adoption	Forming beliefs	Goal-setting
Adapa, A., Nah, F.F.H., Hall, R.H., Siau, K. and Smith, S.N.				■						
Ajzen, I.			■						■	
Atzori, L., Iera, A. and Morabito, G.										
Baber, C., Khattab, A., Russell, M., Hermsdörfer, J., Wing, A.		■			■	■				
Bagozzi, R.P.										
Becker, M., Kolbeck, A., Matt, C. and Hess, T.										
Brian Kiessling, I.I. and Kennedy-Armbruster, C.										
Canhoto, A.I. and Arp, S.	■									
Cecchinato,M.E., Cox, A.L. and Bird, J.						■				
Chang, H.S., Lee, S.C. and Ji, Y.G.		■								
Chuah, S.H.W., Rauschnabel, P.A., Krey, N., Nguyen, B., Ramayah, T. and Lade, S.	■									
Consolvo, S., McDonald, D.W. and Landay, J.A.			■			■				
Dehghani, M.										
Dehghani, M., Kim, KJ. And Dangelico, R.M.										
Duro, L.										
Fogg BJ.			■							
Fritz, T., Huang, E.M., Murphy, G.C. and Zimmermann, T.						■				
Gagné, M. and Deci, E.L.										
Harrison, D., Marshall, P., Bianchi-Berthouze, N. and Bird, J.		■								
Hartson, R.		■								
Hitchings, H.							■			
Jarrahi, M.H. Gafinowitz, N. and Shin, G.	■	■	■							
Jeong, H., Kim, H., Kim, R., Lee, U. and Jeong, Y.		■								
Karahanna, E., Straub, D.W. and Chervany, N.L.	■									
Kim, K.J. and Shin, D.H.									■	
Leão, M.A.D.S.P.		■	■				■			
Li, I., Dey, A. and Forlizzi, J.				■						
Locke, E.A. and Latham, G.P.										■
MacKenzie, D. and Wajcman, J.	■									
Maher, C., Ryan, J., Ambrosi, C. and Edney, S.		■	■							
Mansi, S., Milosavljevic, S., Tumilty, S., Hendrick, P., Higgs, C. andBaxter, D.G.			■							■
Mao, E. and Palvia, P.	■									
Mercer, K., Li, M., Giangregorio, L., Burns, C. and Grindrod, K.			■				■			
Norman, D.A.		■								
Page, T.								■		
Patel, M. and O'Kane, A.A.										
Patel, M.S., Asch, D.A. and Volpp, K.G.		■	■							
Pink, D.H.										
Rogers, E.M.										■
Rooksby, J., Rost, M., Morrison, A. and Chalmers, M.C.										
Shih, P.C., Han, K., Poole, E.S., Rosson, M.B. and Carroll, J.M.			■							■
Shilts, M.K., Horowitz, M., & Townsend, M.S.			■							■
Sullivan, A.N. and Lachman, M.E.		■	■				■			■
Sweeney, J.C. and Soutar, G.N.										
Vallerand, R.J. and Losier, G.F.										
Van der Heijden, H.	■									
Venkatesh, V. and Davis, F.D.										
Venkatesh, V., Thong, J.Y. and Xu, X.										
Visuri, A., Sarsenbayeva, Z., van Berkel, N., Goncalves, J., Rawassizadeh, R.,										
Wu, L.H., Wu, L.C. and Chang, S.C.			■							
Yang, H., Yu, J., Zo, H. and Choi, M.										
Zeithaml, V.A.										

Figure 1: Content analyses second phase (Authors, 2018)

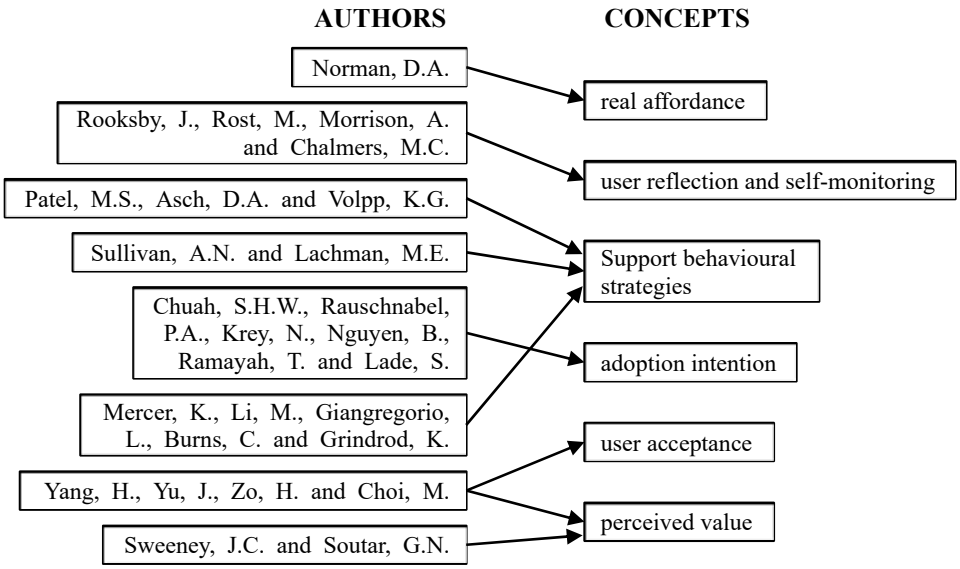

Figure 2: Content Analyses from Literature: First Phase (Author, 2018)

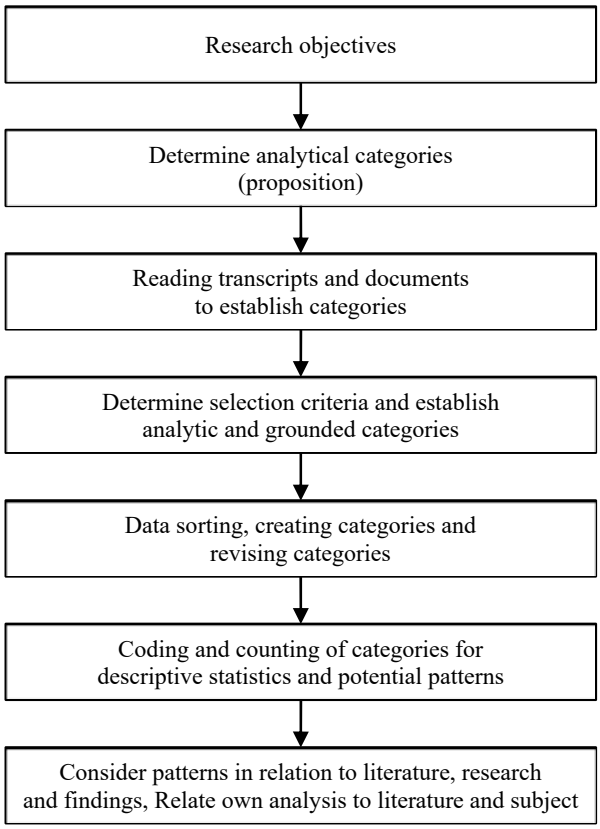

Figure 3: Stage model of content analysis: Adapted (Hancock et al., 2016:59)

Participants at the time of interviewing, were men and women living in Cape Town, owning, owned, used or who were using wrist-worn wearable trackers. Our demographic included older and young individuals between the ages of 23-54, varying in economic backgrounds and activity levels. This was a purposeful attempt in ensuring a variation of user insights and contextual overlap. According to Yin and warning against a disconnect between context and data when adopting a case study method, our process was directed by protocol, involving interviewing current users of wearable trackers, circa 60 minutes (1981:104). Interview recordings were transcribed, analysed and formatted using and inductive approach, in order to categorise and sub-categorise findings (Thomas, 2016: 237). Figure 3 is an adapted framework showing our inductive approach.

These findings supported our empirical assumptions around usage of wearable fitness

trackers and its user affordances. From these, we formulated propositions attempting to explain the associated variables and concepts related to device usage (van Staden, 2019). Collected, coded and thematically analysed semi-structured interview data constituted as our primary source for referencing emergent data. Using Atlas Ti and the lens of Activity Theory we identified several themes from participant interviews. Thematically coded interview data was allocated in relation to its Activity Theory elements, with the individual activity as the unit of analysis. The focus of this study attempted to gain an understanding through the study of artefacts and tools, how human action is influenced and inseparable from a mediated relationship between artefacts or tools and the related components within an activity system. The interrelatedness of an activity system can thus permit influence to occur or affect individual action in relation to tool, subject, object, rules, division of labour, community or tensions and contradictions which may exist as consequence of an interplay between participating activities within an activity system. Data was developed and participant responses mapped according to different Activity Theory criteria.

This allows us to identify redundancies by filtering concepts through Activity Theory. Additionally, we were able to identify tensions and contradictions within the various activity systems (van Staden, 2019). Essentially data was analysed and classified according the activity using the outcomes to developed personas.

5. Summary of Research

This study explored user acceptance and patterns of behaviour related to wearable device use. The study responded to a growing academic concern in that these persuasive technologies, in particular smart watches, represent the most popular type of wearable devices that hold the potential to motivate and influence behaviour (Fritz et al., 2014) and (Chuah et al., 2016:276). Using Cultural Historical Activity Theory as an analytical lens we interviewed eight participants as means of outlining human interaction and the mediating factors accompanying wearable device use. The four personas' overarching themes are further fleshed out below.

5.1 Lifestyle Management

Key benefits of wearable fitness usage are their pervasive ability, utilising smart sensor technologies, to combine and present contextual information for the accumulation and monitoring of personal quantified data (Li et al. 2010). A device's potential ability to encourage engagement and support users in achieving their goals was the primary driver in acceptance and use. Essentially users were inclined to adopt these trackers if it allowed them a means of retrieving relevant information or if it supported lifestyle factors that impacted on a user's overall sense of well-being (Rooksby et al., 2014) and (Li et al., 2010).

5.2 Self-efficacy

Real time information as afforded through interactive displays and haptic feedback informed and supported user's decisions and behaviour in relation to their environment. The aggregation of quantified data was perceived as valuable and pertinent if it facilitated or directed actionable thought. Such reflection allowed for the emergence of new context or self-efficacy allowing users to improve activities based on the knowledgeability of a situation as brought about through device interaction and reflection on quantified data. As an example, for persona 2 device interaction and feedback played a significant role in developing potential capabilities that could yield ancillary outcomes. Li et al. confirms this in their "collection phase", indicating the time users actively accumulate quantified data (van Staden, 2019). This usually incorporates phases of introspection and self-reflection and interaction with people and user context (Li et al., 2010).

5.3 Affordances

Device affordances and its application corresponded to an individual preceding condition, referring to their level of experience, individual goals and physiological capabilities. Essentially the perceived functional affordances of these wearable fitness trackers, aiding user objectives served a less leading role. Evidently the functional affordances of these devices were operationalised amongst other components. Furthermore, that operational knowhow and cause equated to levels of probable functionality and individual user affordances. This is supported by Norman (1999) distinguishing between perceived affordances and real affordances, where real affordances relates to the range of potential action and perceived affordances as linked to the visible perception of such probability. Perhaps lacking in Norman's model are the individual and environment factors that exist outside of the physical object or artefact that aid in operationalising device affordances.

5.4 Perceived value

Device adoption and acceptance depended on an individual context and their perceived needs being met in relation device interaction. This is supported by Karahanna et al. who attribute perceived value, image, compatibility, visibility, and result demonstrability as linked to individual attitudes (Karahanna et al. 1999:188). Objective factors, such as built in features, or features that were exposed through usage, as well as subjective factors influenced users' sense of perceived value. These included vibrational alerts and smart notifications, notifying users of incoming messages or discreet communication or feedback, alerting users through

touch. According to Karahanna et al., these pertain to observable results and communication as consequence of adopting a system or device (Karahanna et al., 1999:188). Other objective factors encompass proportions and proximity (van Staden, 2019). In the case of wearable fitness trackers perceived user benefit related to convenient access to information, additionally end user customisation or the ability to change and adapt information in relation to context. Customisation also allowed a means to assist user objectives through device stimulus or haptic feedback to indicate action or initiate responses. Karahanna et al. term this "visibility", the degree to which device's permutations are apparent to users affect their perceived behavioural beliefs in a particular system (Karahanna et al., 1999:188). Subjective factors referred to individuals' states of mind, reasons for adopting wearable devices, cultural influences and physical condition.

5.5 Community and Normative influence

Community engagement or normative social influences played a significant and influential role in user adoption and sustained personal usage across social groups or context. Community engagement instilled aspirationalism due to normative social influences or social conformity, leading to the adoption of new behaviours or experiences (van Staden, 2019). Device engagement as such generated social affordances allowing users a means to communicate and compare personal values, objectives and beliefs amongst social convention or groups. Additionally, as an affordance it permitted self-reflection and the ability to self-evaluate by social comparison. Furthermore, usability factors such as step counters and smart notifications that support comparative analysis amongst social allowed users to measure and validate personal goals or experiences (Zeithaml, 1988 and Sweeny et al., 2001).

5.6 Self-awareness, Reflection, Goals and Motivation

Device utilities, for-instance a heart rate monitor and smart sensors, in accessing pertinent health information aided in physical rehabilitation and generating self-awareness by allowing continuous reflection on captured data. Additionally, this ensured and supported the cumulative adaptation of behaviour over time. Device usage, socially, also instilled in users a feeling of wellness and emotional connectedness by being able to share experiences with others. This derived by being able to curate an environment through device interaction, such as controlling a playlist uninterrupted. Self-reflection occurred by curated and quantified data that users would upload onto a social platform. This act of social sharing served as both a benchmarking and celebrating progress instilling a sense of achievement. It also assisted user to stay active, motivated healthy and positive (van Staden, 2019). The real time immediacy and attainability of information as accessible through the device's interactive displays assured that physical activities did not compromise the user's physiological capabilities and limitations, avoiding potential physiological stress.

Additionally, this allowed for easy transition or adaptation of their behaviour as a result of device interaction and usage. As supported by Mansi et al. who suggest that incremental goals that seem achievable are more likely to offer actual behavioural change (2015:6). Furthermore, the process of capturing quantified data for personal reflection provided peace of mind. As an example, persona 2 own developmental awareness occurred as a result of the process of such reflection on captured data that was mediated according to their contextual relevance. This informed user's decision making based on whether such interaction and affordances offered opportunity for action or reflection in relation to individual choice, needs and environment (van Staden, 2019). As an example, where the objective was to decrease sedentary behaviour, development was only initiated based on the user's knowledgeability of a situation or context of progression as afforded by device interaction or quantified data. This increased awareness contributed to a more mindful approach when applied to a personal training plan or adjustment of routine, especially when activity summaries or qualified data was accessible. This facilitated goal orientated engagement such as participating in fitness challenges or social events (van Staden, 2019). Partaking in a social event provided additional motivation towards actions. This is in part supported by Locke and Latham who posits that challenging goals has a direct and positive association with high achievement outcomes, provided it is matched with an individual ability towards achieving set goals (2002:706).

For example, in the instance of persona 3, self-awareness and reflection occurred within active event participation (van Staden, 2019). This was done by using GPS tracking, smart sensors, heart rate monitoring and other device attributes that monitor progress which would trigger in situ transformation based on the contextual relevance of transmitted device information. The intensity of exercise and progress made could be assessed in real time, generating situational awareness. The sharing of quantified device data, on a social platform, also served to validate user performance and contributed to the larger of objective of maintaining an active life that included social and communal comparison. In another example, persona 4 used device interaction to form part their goal of gamifying their lived experience (van Staden, 2019). This entailed using collected quantified data that was incentivised either on an incentivised platform or reward-based system. This act of earning

rewards or points served as both a goal and motivation that generated a sense of achievement that brought about positive feelings regarding physical exercise leading to healthier lifestyle choices.

6. Conclusion

The content analysis application to the literature regarding the affordances of smart devices, contributes to the future study of wearable fitness trackers and the current constructs and categories that are directing scientific discussion in peer reviewed journals. Our study contributes to an increased understanding of the specific value offered by wearable fitness trackers, as well as an increased awareness of the variables with respect to use and context. The ability to support users in achieving their goals had an impact on the user's acceptance of and engagement with the device. (van Staden, 2019). Therefore users are likely to adopt these devices if it allowed them a means of accessing relevant information or in that it supported a number of lifestyle factors that impacted on a user's overall sense of self or well-being.This resonates with Rooksby, Rost, Morrison and Chalmers (2014) and Li, Dey and Forlizzi (2010) who speaking of personal informations or lived informatics states that user reflection and self-monitoring in its application varies, largely as consequence of dynamic and changing user motivations, their environment and personal preferences.

Furthermore, we found that by motivating and supporting smaller, more manageable goals, wearable devices were more likely to contribute to actual, positive behavioural change within the user, as supported by Mansi et al. (2015); (van Staden, 2019). This entailed either using accumulated quantified data which were transform on an incentivised platform or where activity summaries or quantified data formed part of a training plan or self-structured routine or it drove goal orientated engagement. Moreover, the socio technical affordance of these devices' ability to permit social actions and exchanges to occur between multiple user groups across different platforms have been found to be drivers that effect device adoption. Additionally, the perceived social acceptance gained by conforming is a motivating factor in the adoption of new behaviour by users. (van Staden, 2019). This is supported by Mao and Palvia (2006) who found that the intention to use information technology is forecaster for real behaviour, however social and cultural context plays a role.

Recommendations

This study has shown that the functional affordances of wearable fitness devices were initiated by active engagement with key device elements. This operational knowhow and purpose, and the corresponding levels of potential functionality may provide personalised user affordances (van Staden, 2019). Recommendations for further research should include an exploration of how wearable technology, in particular wrist-worn activity trackers, activate external or environment factors that exist outside of the physical object or product and how it may facilitate personalised user affordances. Furthermore, how the notion of community may be further supported by these devices in supporting user objectives as being part of larger or diverse contextual environments.Additionally, regarding policy and practice it would be beneficial to uncover in more detail and with a larger sample size what some of the contextual, environmental and device conditions are as they pertain to the use of wearable devices that contribute or directly affect adoption criteria and behaviour.

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