AN AFFECTIVE, NORMATIVE AND FUNCTIONAL APPROACH TO DESIGNING USER EXPERIENCES FOR WEARABLES

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ABSTRACT

This research article considers the problem of sustained user engagement within wearable computing devices (wearables) which make up an important segment of the growing Internet of Things. While these devices have received proliferated adoption, they appear to be abandoned after a period of use – a situation which is of concern to industry stakeholders. To address this problem, we adopt an action design research approach, which emphasizes the interaction of designers, users and experts in shaping the design of IT artifacts, to develop a comprehensive set of design principles for wearables. Our findings are as follows: we identify 3 main theoretical perspectives to inform this endeavor - an affective quality perspective, a social norms perspective and a utility accrual perspective. From these perspectives, we further derive 6 actionable design principles - sensor based interaction, normative adherence, isolated functionality, complementary value, glanceability and computational offloading.

KEYWORDS: Wearable Computing, Action Design Research, Social Norms, Affect, User Interface

EXECUTIVE SUMMARY

One trend that rivals and stands to potentially eclipse the transformational effect of the smartphone, is the rise of wearable computing devices. Also known as wearables, they are a class of miniaturized electronic devices worn by the bearer on top of or beneath their clothing and make up an important segment of the growing Internet of Things. Generally, they possess 3 main components – hardware sensors that enable them observe their physical environments, built-in processors to analyze observations, and communication modules to relay information to other machines (Atzori et al. 2010) . On one hand the hype and adoption of wearables appears to be steadily increasing - a survey of 6,223 US adults showed that 10% of all customers owned a modern wearable activity (Ledger and Daniel 2014), the figures also point to concerning results regarding sustained engagement with these devices - 50% of these respondents indicated that they had discontinued the use of their devices and a third of the this number stopped using the device within six months (Ledger and Daniel 2014). It appears that users tend to easily get "bored" of these device and simply discontinue their use. Given that the interface design of technology artifacts has been linked to usage behavior, this study aims to tackle the sustained engagement issues of wearables by developing a robust set of design principles which takes into consideration the affective quality, social norms and utility aspects of these devices. Using and action design research approach and smartwatches as a context, the results of this study benefits from rich interactions with developers, users and experts. In summary, we derive 6 actionable design principles - sensor based interaction, normative adherence, isolated functionality, complementary value, glanceability and computational offloading which can guide the design of wearable computing interfaces.

1. INTRODUCTION

Wearable computers (wearables), are a class of miniaturized electronic devices worn by the bearer on top of or beneath their clothing. Like the smartphone, they hold potential to transition from individual/personal usage to enterprise usage. In addition to their improved sensing capabilities, reduced size and ubiquitous nature, these devices also take on additional societal or normative implications as objects “worn” on a person. Generally, they possess 3 main components – hardware sensors that enable them observe their physical environments, built-in processors to analyze observations, and communication modules to relay information to other systems (Atzori et al. 2010). For example a fitness tracker worn as a band on the wrist contains an accelerometer and gyroscope sensor which can track steps, a processor which analyzes this data and a Bluetooth communication radio which connects it to a smartphone where the data can be further processed. Today, wearables come in different form factor ranging from smart glasses worn on the face, fitness trackers or smartwatches worn on the wrist, upper arm, and chest, jewelry with embedded chips, to devices clipped to or embedded into clothing, contact lenses and tattoos. Concrete examples includes the Oculus Rift virtual reality goggles, Google Glass, Nike Fuelband fitness tracker, Jawbone fitness tracker, Fitbit fitness tracker, Pebble Smartwatch, Samsung Galaxy Gear smartwatch etc. Of all the wearable devices available today, smartwatches and fitness trackers appear to be the most promising. For the purposes of this study, we have selected the smartwatch as our context for the following reasons. First, smartwatches have a higher market penetration and adoption rate than other wearable devices. A survey of 4600 adults in the USA suggested that 28% of respondents are interested in wearable devices worn on the wrist as opposed to 12% interested in devices worn on the face or 15% for those interested in cloth embedded devices. Also, industry forecasts from CCS consulting (Spencer 2014) expect significant increases in the sales of smartwatches and predicts shipments to exceed 68million devices in 2018 compared to less than 4 million devices shipped in 2013. Second, smartwatches are *flexible* and allow for the installation of modular applications (apps) capable of adapting the device to multiple use cases. These apps essentially become a core driver of device utility and adoption. Third, the flexibility of smartwatches create opportunity for its adaptation to enterprise functions, making them the most likely wearable device to have implications for organizations, especially within the framework of the BYOD and IT Consumerization phenomena (See Harris et al. 2012).

The user interface of any given technology artifact represents the sum of all possible channels through which humans can provide input to and receive a response from same artifact. Interface design is an important factor in HCI considerations because it has been observed to influence a core part of human behavior and motivations, known as *Affect* (Van der Heijden 2003; Zhang and N. Li 2005). Affect is a generic term which describes concepts related to emotions, moods, feelings (Bagozzi et al. 1999; Liljander and Mattsson 2002; Russell 2003) and influences aspects of individuals such as reflex, perception, and cognition (Forgas and George 2001; Forgas and Moylan 1991) . The degree to which an artifact or stimulus (in this case, the user interface) can cause changes in an individual’s affect, is known as affective quality (Mehrabian and Russell 1974; Russell 2003). In essence, a good user interface improves the affective quality of an artifact and this in turn, influence multiple outcomes such as satisfaction (Hess et al. 2006) , performance (Schenkman and Jönsson 2000) , perceived usability (Tractinsky et al. 2000) and adoption (Van der Heijden 2003; Zhang and N. Li 2005) .

In their overview of the broad issues regarding HCI research, (Zhang and N. (Lina) Li 2005) position interaction as the core of all HCI studies , and further identify two sub components of interaction research - design and impact use . Their evaluation of the distribution of current HCI studies across these two subcomponents reveal two important gaps in the literature.

First, it is shown that that 77.6 % of all published research fell within the area of IT impact use as opposed to IT artifact design. While the design of appropriate user interfaces for information systems has been long acknowledged as an important aspect of the IS discipline (Keen 1980; Zhang and N. (Lina) Li 2005; Zhang et al. 2002), most of the work being doing today mainly focuses on impacts (behavioral responses) of existing user interfaces or user interaction. While it may be argued that the actual design (technical specifications) of an artifact prior to release and use may lie within the purview of computer science research, a *theory inspired* and *human interaction* approach to this technical design falls within the domain of IS research ; and more work needs to be done at this intersection. The second aspect of HCI research that can benefit from further attention is a diversification of study contexts. Existing study contexts tend to focus on broader HCI issues within the organization or the workplace context with little emphasis on non-work contexts. In their review study, (Zhang and N. (Lina) Li 2005) found that 83.9% of all studies conducted in the HCI sub field focused on the Organization and the workplace context followed by 8.9% which cover the market place context. It is interesting to note that their classifications do not cover the emerging "ubiquitous" context which has become increasingly important with the rapid consumerization of IT (Harris et al. 2012b). From the literature perspective, this study is well positioned to make contributions to HCI research by addressing design aspects of interaction and also accommodating emergent contexts. In the early 80s, the notion of extending the use of computers from large corporate companies to individuals was absurd. Computers were physically massive, very expensive and fairly complex to operate. Why did individuals begin to adopt the personal computer meant for "industries"? Similarly, in the late 90s, it appeared doubtful that the exciting and intriguingly capable smart mobile phones would catch on and receive widespread adoption. Why would people ditch the real estate and capabilities of their desktops and laptops in favor of smart phones for tasks such as surfing the internet, taking notes, e-commerce and social networking? In hindsight, it is widely acknowledged that the successful adoption of the pc was spurred by the success of the Apple II computer which pioneered the implementation of a graphical user interface, a user friendly interface and had multiple well-articulated use cases. Similarly, the introduction of the iPhone and iPad which introduced innovative applications and user interactions marked a positive change in the general perception and adoption of smartphones and tablets respectively. Smartphone usage has eclipsed pc usage (Weintraub 2010) . To get users to adopt a new technology, vendors must be able to motivate its potential to "simplify human life". At the heart of this simplification is the ability to develop truly affective user experiences for new device form factors and provide access to vital functionality in a timely, ubiquitous and effort-free manner.

1.1 WEARABLES AND THE SUSTAINED ENGAGEMENT CHALLENGE.

As the next wave of technology arrives, in the form of wearable computers, that familiar doubt regarding its possible success arises again. On one hand the hype and adoption of wearables appears to be steadily increasing - a survey of 6,223 US adults showed that 10% of all customers owned a modern wearable activity tracker such as the Nike+ Fuelband, Jawbone, and Fitbit etc (Ledger and Daniel 2014). It is also predicted that in the coming decades, wearables will not only be worn on our wrists and faces, but will be seamlessly integrated into our clothing, designed as part of our jewelry and even painted on our skins (Ariel Bleicher 2014).

However, the figures also point to concerning results regarding sustained engagement with these devices - 50% of these respondents indicated that they had discontinued the use of their devices and a third of the this number stopped using the device within six months (Ledger and Daniel 2014). It appears that users tend to easily get "bored" of these device and simply discontinue their use. We believe this may be as a result of two main factors. Generally, we conjecture that the current set of user interactions and use cases for wearables struggle to generate an affective quality sufficient to drive sustained engagement. This may occur due to several reasons. First, given the nascent nature of wearables, there is a dearth of widely tested design principles that drive engagement, compared to their smartphone and tablet counterparts. Second, wearables have a panoply of unique characteristics that must be taken into consideration when designing interactions for them. They are resource constrained (relatively low processing, storage and communication capabilities), have reduced interaction surfaces and take on additional social or normative implications as objects "worn" on a person. These

characteristics make the current set of interaction guidelines for devices such as smartphones and tablets less relevant to the wearable context.
In this study, our aim is to address the user-engagement challenge regarding wearable computing devices, by creating a revised set of theoretically inspired user interaction design principles that can guide developers and designers who create software for wearables. In so doing, this study is well positioned to make contributions to HCI research through an examination of design aspects of interaction and extending HCI studies to observations in ubiquitous contexts. We believe this study is timely, and the relative nascence of wearable devices provides an opportunity to bridge the lamented gap between theory and practice (Benbasat and Zmud 1999; Iivari 2002; Rosemann and Vessey 2008), and also "lead" industry.

1.2 AN ACTION DESIGN RESEARCH APPROACH

Action design research (ADR) as proposed by (Sein et al. 2011) refers to an IS research approach that aims to explicitly recognize how interests, values, and assumptions about an organization or people shapes the design of IT artifacts. ADR is consistent with the dual mission of IS research regarding making sound theoretical contributions as well as developing solutions to problems faced by practitioners (Benbasat and Zmud 1999; Iivari 2002; Rosemann and Vessey 2008). It moves a step further in helping resolve the repeatedly identified disconnect (Benbasat and Zmud 1999; Dennis 2001) between IS research output and the needs of practitioners. ADR asserts that IT artifacts are "ensembles shaped by the organizational context during development and use" and the design research process should encompass the concurrent activities of building an artifact, its interaction with an organization and its evaluation.

Stage	Principles
Problem Formulation	1. Practice - inspired research 2. Theory ingrained artifact
Building, Intervention , Evaluation (BIE)	3. Reciprocal shaping 4. Mutually Influential Roles 5. Authentic and Concurrent Evaluation
Reflection and Learning	6. Guided Emergence
Formalization of Learning	7. Generalized outcome

Table 1.0: Action Design Research Stages.

ADR combines the tenets of pure design science research and action research. On one hand, while design science research emphasizes on the development and evaluation of IT artifacts that solve an identified class of problems (Dennis 2001; Hevner et al. 2004) , action research combines theory development and field research to solve immediate organizational problems (Baburoglu and Ravn 1992; Baskerville and Wood-Harper 1998) . ADR specifies a 4 stage research process and associated principles which is adopted in this research study. In so doing, we achieve two research goad namely: our activities are a design intervention with practical goals (helping developers design better user experiences) as well as a theoretical exercise (articulating and evaluating design principles to guide the development user interfaces for the emergent class of wearable computing devices).

2.0 RESEARCH SETTINGS

Our research setting is loosely modelled around the series of events and interaction platforms associated with a crowdsourcing contest (Samsung Gear App Challenge)[1] held by Samsung Electronics (May 2014 – November 2014), inviting developers to submit apps for their recently released *Gear 2* line of smartwatch devices.

Launched in April 2014, the Gear 2 smartwatch runs Samsung's proprietary Tizen for Wearable Operating System and has hardware features such a heart rate sensor, infrared blaster, camera, gyroscope and accelerometer. With 4GB storage, 512MB internal memory, 1.63 inch super AMOLED touch screen, the device holds promise to provide value in the area of health tracking, simplification of tasks, and contribute to the larger Internet of Things concept (see Atzori et al. 2010; Medaglia and Alexandru 2010; Miorandi et al. 2012) .

Given the relative infancy of the Samsung Gear 2 platform at launch, there were only a limited amount of software applications, insufficient to meet diverse range of user interests and potential use cases. To enrich their application ecosystem, Samsung thus initiated an incentivized software crowdsourcing contest to run between the periods of May 2014 to September 2014. It is important to note that the Gear 2 device implements the platform model of software(Dibia 2015; Tiwana et al. 2010) where an intermediary platform (Samsung) mediates exchanges between multiple developers and multiple users. The developer create apps which are uploaded to via an administrative portal (Samsung Seller Office) to the platform for approval and distribution to users. Users can then browse the collection of submitted apps and make purchases via a software application (Gear Manager app) running on their smartphones. The Gear Manager app then installs these apps on the users' connected smartwatch and provides an opportunity for the users to leave feedback about the app.

The contest, which was run on an independent crowdsourcing platform (ChallengePost, CP[2]), had two rounds. 200 submissions were initially selected as first round winners in August 2014 and 40 submissions declared as second/final winners after the contest duration elapses in September 2014. For the contest, 2842 developers registered an initial interest in participating in the contest, and after the 2 months allocated to round 1, 573 developers successfully made 927 submissions (apps). During this contest period, developers could interact with each other (as question, respond to questions) primarily through two online channels. They could post on the CP discussion forum for inquiries related to the contest or the Samsung Developer Forum (SDevForum) for application development (technical) or design related inquiries.

2.1 APPLYING OF THE ADR PROCESS

Given that ADR emphasizes the process of design of an artifact and its evolution through interaction with the organization, it is important to specify the nature of the artifact and the members of the organization in this study. Our artifact here is a *set of design principles* and the organization includes *system designers and developers* who build software for our chosen context - smartwatches.

[1] The Samsung Gear App Challenge invited developers to take technology to the next level by creating innovative, functional, and original apps for the Samsung Gear 2 device. In over two rounds, developers will have the chance to win $1,250,000. http://gearapp.challengepost.com/

[2] ChallengePost is a platform that enables companies, non-profits and individuals to create (software development) contests and award prizes for solving problems. http://www.challengepost.com

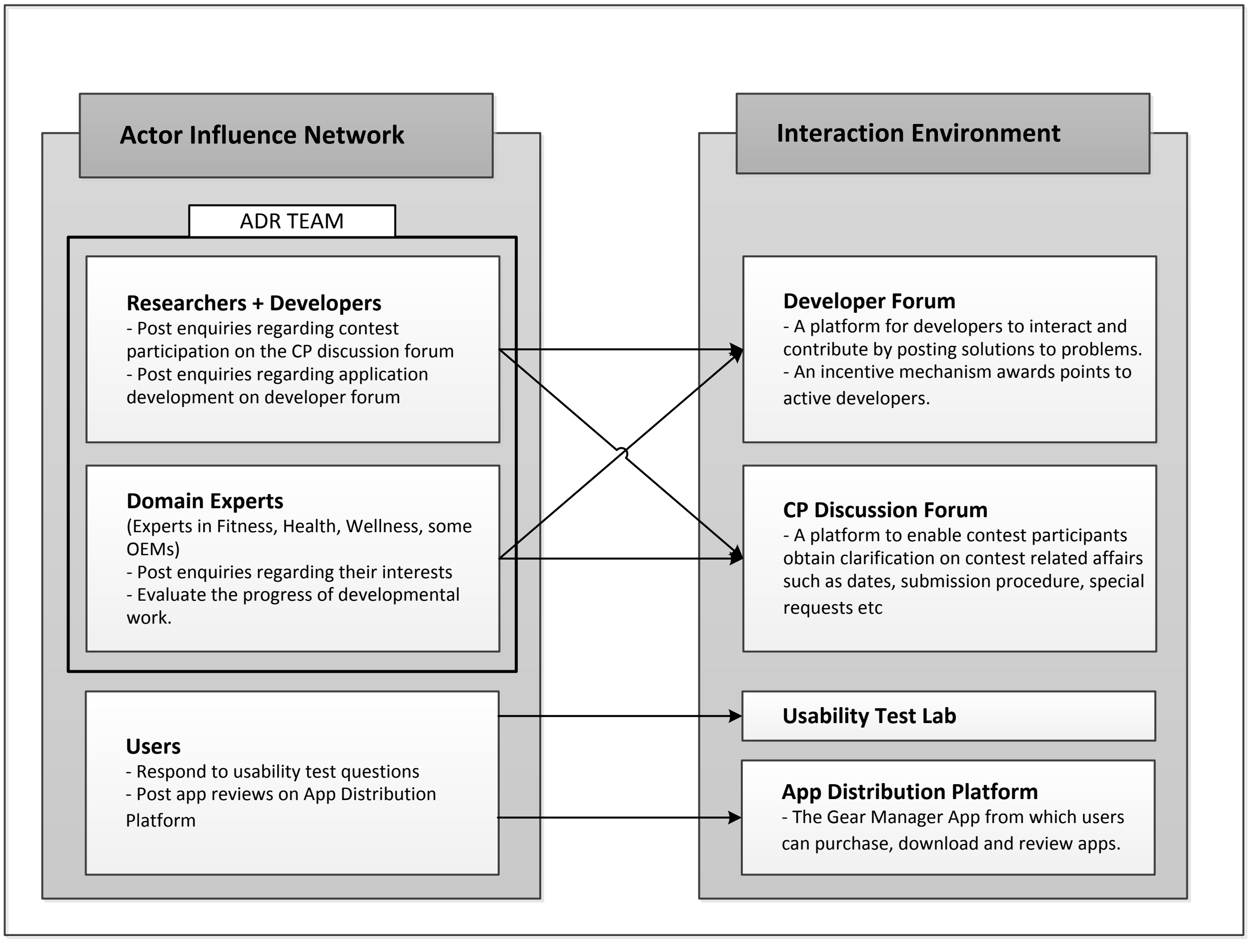

Figure 1.0: Detailed View of the Actor Influence Network and Interaction Environment that make up our research setting.

Within this study, the sense of an organization is slightly different. As opposed to a large firm with multiple departments and employees, we treat a developer team working on an app as a single organizational entity. To capture organizational influence, we set up an ADR team (Sein et al. 2011, p. 46) in which one of the researchers in this study worked closely with one such developer team in developing 5 applications for the Gear 2 smartwatch. The ADR Team also included input from domain experts (health, wellness, sports, fashion etc.) interested in applications for the Gear 2 line of devices. Also, (Orlikowski and Iacono 2001, p. 131) expound that the interaction aspect of design research includes influences from developers, investors and users, thus we evaluate design aspects and concerns generated by both users as well. The development of our design artifact is derived through intervention influences from, users and domain experts (See Figure 1). We refer to these three as our *actor influence network*. Our implementation of ADR is similar to the participatory approach of (Rosson and Carroll 2013) and (Lindgren et al. 2004)where the authors work with a development team in building an online community for women in computer and information sciences and with a team of developers in creating a tool for competence management respectively. This approach is also beneficial because it promotes the cross-fertilization of expertise between system developers and end users (Kyng 2010).

The ADR team for this study also communicated with other teams across multiple interaction environments (see Figure 1.0). There were technical exchanges between the ADR team and other developers via the CP discussion forum and SDev forum. Both forums were also open to domain

experts who would occasionally share their ideas or post enquiries related to their interests, creating an opportunity to also engage this segment of our influencer actor network.
To observe the evolving user interactions with the devices, we conduct usability tests with 5 participants. We have supplemented this with information from comments posted on the Samsung app platform regarding each app, and user comments from online reviews
Problem Formulation
In this section, our aim was to frame the sustained engagement problem as a knowledge creation opportunity and develop a design framework that addresses a generic set of interaction design problems related to developing interfaces for the wearable class of devices.
We began by examining the first version of the apps developed for the contest by our ADR team. From our initial examination, we diagnosed several issues across each app - fuzzy functional implementations and diminished poor visual appeal as central problems with app interfaces. We also conducted a survey on the CP discussion forum which invited the developers to discuss any UI design challenges they may have encountered whilst building apps for the smartwatch. Findings from developer reports can be classified into issues regarding accessing the appropriate resources to create their interface, and issues regarding technical decision making processes during the interface creation process (see Table 2.0). The findings also double as the outcome of possible brainstorming by a group of developers.

Categories	Issue Summary based on Developer Feedback.
Resource Gathering Deficiencies	- There is a lack of samples and documentation, - Existing samples were considered not suitable to our contexts - We didn't have a dedicated designer
Technical Difficulties	- It was a struggle to adapt our designs to the small screen of wearables - The devices had limited capabilities (direct internet connection, a magnetometer etc.) - It was difficult to balance our adaptation to the small screen and maintain accessibility - Mismatch between emulator and real device - Designing an engaging user experience flow was a challenge

Table 2.0: A summary of design issues reported by developers.

3.0 THEORETICAL UNDERPINNINGS AND FORMALIZED LEARNING

To adequately frame findings from intervention influences with our actor influence network, and as stipulated by the ADR process, we review the literature for theories that guide the construction of working hypotheses which are then implemented and tested. We adopt three main theoretical lenses – an affective quality perspective, a social norms perspective and a utility accrual perspective. Based on each of the perspectives, we then put forward our working hypothesis and a set of refined design principles derived from interactions from our actor influence network.

3.1 AFFECTIVE QUALITY PERSPECTIVE

From our understanding on the literature regarding interfaces (Zhang and N. Li 2005), we conjecture that well-designed user interfaces should evoke favorable, affective responses from users and support the achievement of specific objectives. Specific aspects of interface design include specifications on visual appeal and its mechanics i.e. how input is received from the user (e.g. voice, touch, gestures, and video) and how a response or feedback is relayed to the user (e.g. textual, audio, video, haptic). Our first working hypothesis is that interfaces with visual appeal and fluid mechanics will lead to improved performance.

Principles

- Principle 1 : Sensor Based Interaction
  This principle suggest an expansion of the limited interaction surface of wearable computing devices by leveraging sensors. For example advanced touch gestures (tap, swipe, pinch and zoom), motion and voice can be leveraged for input while vibration can be leveraged for personalized feedback.

3.2 SOCIAL NORMS PERSPECTIVE

Studies have considered social and normative factors as key drivers of adoption and usage behavior (Malhotra and Galletta 2004). Particularly, the theory of reasoned action by (Ajzen and Fishbein 1970) suggests that an individual's perception of what other important people think (subjective norms), will influence behavior . From the perspective of identity, studies have examined IT as an enabler of self-expression (Livingstone 2008; Ma and Agarwal 2007), and the design of IT to enable congruence between real self and virtual self (Jensen Schau and Gilly 2003) in order to minimize anti-social online behavior . The general class of wearable computing devices, are objects worn on a person's self and in many circles, carry normative significance as a way of expressing identity and as an item of fashion as well. Our second working hypothesis is that interfaces which conform to subjective norms will lead to improved performance.

Principles

- Principle 2 : Visual Normative Adherence
  This principle suggests that interfaces should be designed to conform to expectations of both wearable technologies and fashion items. For example, watch face apps for smartwatches should be designed such that they are both meaningful and elegant.

3.3 UTILITY ACCRUAL PERSPECTIVE

The promise of IT has always been hinged on its ability to simplify processes and improve task performance (Jasperson et al. 2005; Lucas and Spitler 1999) . Users expect to derive clear, demonstrable and measurable performance gains from the adoption of IT. We consider this expectation of performance gains as utility accrual behavior, and thus our third working hypothesis is that interfaces which provide clear functional benefits to users will lead to improved performance.

Principles

- Principle 3 : Isolated Functionality
  This design principle posits that each wearable device app should be clearly developed to meet an given and well specified user need as opposed to generic apps with multiple functions.

Where possible, apps should be tied to specific outcomes that are of significance to a given set of target users.

- Principle 4 : Complementary or Incremental Value
  This principle suggests that the value of a wearable app is tied to how well it performs its focal task compared to similar apps on other device platforms such as smartphones and tablets. This performance based value may be realized from application to specific contexts or by software filtering. For example a wearable device that tracks exercise regiments is "handier" to use in the gym compared to a smartphone. Similarly a wearable device can provide value by automatically providing notification only from important contacts such as family members.
- Principle 5 : Glanceability and Actionability
  This principle suggest that notifications should be designed such that they are easy to read (legible), assimilate within a simple glance and can be responded to with simple actions.
- Principle 6 : Computational Offloading
  This principle suggests that complex or resource intensive tasks should be transferred to devices with higher processing capabilities where possible or applicable. For example, a wearable device may perform resource intensive operations like audio sampling, geocoding or data processing on a connected smartphone or tablet and display results to the user.

To evaluate the hypothesis, we endeavored to translate each of the principles to implemented features in selected apps within the apps the ADR team was working on. The updated version of the apps were then tested with our panel of user testers to give a rating on their perception of the user interfaces. We also monitored feedback from users who downloaded the apps to monitor the impact of changes on user opinions.

4.0 CONCLUSION

In this study, our purpose is to address issues regarding building interfaces for wearable computing devices that are affective and can sustainably engage users. Wearables, as a class of devices have a set of limitations (reduce processing and power capacity, limited interaction surfaces, small size) and advantages (enhanced sensing capabilities, high ubiquity) which designers must take into consideration when creating interfaces for them. Using the smartwatch as our context, and adopting an action design approach, we identify three main theoretical perspectives that inform the design of wearable computing interfaces. An affective quality perspective, a social norms perspective and a utility accrual perspective. From within these three perspectives, six exemplified and actionable guidelines are derived which can directly inform design endeavors for practitioners.

From the theoretical perspective, this work also makes important contributions. As opposed to conventional HCI research approaches which conduct usability or impact tests of existing UI models, we adopt theory inspired and empirically tested ideals in building actual *novel* and *practical* design guidelines that are positioned for greater impact. In so doing, we also contribute to the sparse academic literature the examine design beyond the organization.

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