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The Future of Wearable Technologies in Daily Use: Interaction & Acceptability

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Until recently, mobile computing has been confined to conventional computing form factors: laptops, tablets and smartphones, which have achieved specific design standards in form and interaction. However, a new stage of computing technology at the beginning of the 21st Century, linked the personal and pervasive, by combining mobile technology with ambient Intelligence (AmI), giving rise to wearable technologies (WT).

Placing technology on one's body, however, is significantly different from using stand-alone devices like laptops. A wearable device is more like a piece of clothing, and clothing has been shown to help define identity, and position oneself (and others) in culture. Raymond Loewy's MAYA principle gives us further insight into, why devices like the Google Glasses that did not fit into the user's present understanding of computing technology, were rejected.

This paper focuses on bringing WT into the last stage of innovation diffusion (Rogers, E. 2003), by leveraging it within ubiquitous computing system environments, to enhance human experiences in daily life and merging it into social culture. It further investigates dimensions of interaction & user experience of WT and its effect on user acceptability. The goal is to make technology more accessible by focusing on environment interaction instead of device interaction.

Keywords*: Wearable Technology; User acceptability; User interaction; User Experience; Ubiquitous computing; Ambient Intelligence; Machine Learning; Human-computer Interfaces*

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Introduction

In his paper, 'The computer of the 21st century', Mark Weiser (1991) first used the term ubiquitous computing (Ubicomp/UC) to describe PARC's (Paolo Alto Research Centre) vision of reinventing the future. Instead of extending the old computer revolution into new widgets and gadgets, they were at the dawn of a whole new revolution. Weiser and his PARC colleagues were keen to steer attention away from the technological devices and in a different direction, as they claimed, towards people themselves.

Defining ubicomp as an essentially human-cantered approach, Weiser and his colleagues construct a story of dualisms that is based on the concept of invisibility (Kerasidou & Charalampia, 2017, p. 595). The idea was to move focus away from the machines and the technical, and instead concentrate on people and the social environment. In Weiser's words: 'Machines that fit the human environment instead of forcing humans to enter theirs, will make using a computer as refreshing as taking a walk in the woods.' Weiser's fundamental premise; namely, the premise that invisibility, a key characteristic of his vision of ubiquitous computing, is 'a fundamental consequence not of technology but human psychology', it focuses innovation to what is really important in life 'away from emphasis on the machine and back to the person and his or her life in the world of work, play, and home'. He goes on to mention that 'The real power of the concept comes not from any one of these devices—it emerges from the interaction of all of them.' (Kerasidou & Charalampia, 2017, p. 602)

There is no longer a need for a single device that does everything, rather there exists a network of devices all around the user that are in constant communication with the user and each other to accomplish tasks as and when needed. Weiser's essay promises technologies that will disappear and 'weave themselves into the fabric of everyday life' (Bradzell, 2014, p. 779). It fleshes out this promise by exploring a number of speculations about the technologies, such as ever-shrinking and ever cheaper processor that would power computational objects that would enable this weaving. Five years later, Weiser and his colleague John Seely Brown (1996) updated this vision in an essay called 'The Coming Age of Calm Technology,' in which the two authors develop the speculative dimension of the ubicomp vision by imagining the implications of people having to interact with hundreds of computers that surround them at any given time.

Weiser & Brown (1996) proposed a new model of human-computer interaction, which they dubbed "calm technology." The idea is that with hundreds of processors per person, technology cannot be the centre of our attention the way it is today, or it will overwhelm us. Instead, they argue that it should enter and exit our attention gracefully, moving from periphery to the centre of attention as needed. Calm technologies will alter human perception itself, by extending our peripheral reach.

Most of the predictions and speculations that the authors made about the advancements in technology that allow the possibility of a world in which ubiquitous computing is a reality, are coming true today. Until recently, mobile computing has been very much confined to conventional computing form factors, i.e., laptops, tablets and smartphones, which have achieved a standardized design in outlook and shape. However, most industries are recognizing the importance and need of a shift in the way technology is consumed by the masses. In their predictions for trends in 2018, Fjord, A leading design and innovation company, predicts that 'Digital is no longer the centrepiece of experience. Emphasis is shifting onto how best to use it as an invisible enabler of physical and sensory experiences. As interactions with users evolve from periodic engagements via a screen to consistent, connected experiences, organizations must create new services that are deeply integrated in the physical world' (trends.fjordnet.com). The more a technology develops, the more it becomes a part of everyday life (Armağan & Çiğdem, 2011, p. 1). At this stage, thought needs to be given as to how these systems will fit into our current understanding of technology, and the necessary changes in standardized (over the past century) interactions and experiences required, for this form of technology to reach its potential and indeed become the norm of technology in society.

Literature Review

Interactions within Ubiquitous Computing & Ambient Intelligence Systems

The ideas envisioned by Weiser in 1991 have evolved into what we today, call Ambient Intelligence (AmI). AmI represents a new generation of user-centred computing environments aiming to find new ways to obtain a better integration of information technology in everyday life devices and activities (Jose, Fuentes, & Ipina, 2011, p. 315). AmI environments have devices of modern life that are fused with computational technology and sensing capabilities. Ideally, people in an AmI environment will not notice these devices, but they will benefit from the services they provide them (Jose, et al. 2011, p. 315).

However, there still exists a platform (which in most cases is made tangible through a screen) in order to use technology spread across an environment, thus defeating the purpose of UC itself and bringing focus back to a central control device that is very visible and becomes the centre of interaction.

> *As we move forward from the personal workstation model of computer use to cloud computing and ubiquitous computing, we also need to begin thinking about accessibility in new ways. The traditional approach of "adapting the machine in front of you," which was the primary focus of technology devices in 1992 and can be very effective in the personal workstation model today, breaks down as we move to a future of ubiquitous computing. (Vanderheiden, 2008, p. 10:4)*

Weiser's work, while being very accurate to predict the way technology would evolve, have fallen short in consideration of interaction with these invisible technologies.

Limitations of Sensing Mechanisms

To overcome limitations in interaction with UC, research efforts in the field of human-computer interaction (HCI) are invested in augmenting technologies with various "sensing" mechanisms and experimenting with different input modalities that allow them to reach their full potential. One of the most important contributions of technology and the internet of things (IoT), is the capability of context awareness. The integration of ubiquitous sensing and networking technologies enables the development of new applications in a wide variety of domains. Current research efforts focus on HCI through natural and intuitive modalities including hand/body gestures, face recognition, gaze/eye tracking, bio-signal analysis, speech recognition, activity recognition and their related issues in functionality (Paravati & Gatteschi, 2015). Devices that are augmented with such sensing mechanisms are aware of the people present within environments by reacting to their gestures, actions, and context. While these areas of research do help push the boundaries of input functionality and work well by themselves in closed and controlled environments, their sensing capabilities fall short as the network of devices grows to be more complex and include more tasks. These limitations of new HCI methods make them a far from viable solution (at least in the near future) for sensing user needs and are not ready for commercial application.

It is commonly understood that the goal of any form of technology is to achieve or complete a specific task. In the case of AmI, the environment makes the accomplishment of a task easier by allowing the technology to anticipate the needs of the user and carry the activities out without the need for user intervention. A simple example of this is a dustbin that senses an approaching user and opens the lid for the user. Thus reducing the number of steps required to carry out the task of throwing garbage away. The use of ambient technology helps accomplish tasks more easily. However, as the complexity of the task increases, the process of anticipating (or sensing) user needs also becomes more complex. Consider the task of collecting ingredients to make breakfast. Here, the sensing of proximity is not enough. These AmI technologies thus need some form of Artificial Intelligence (AI) that helps read situations to predict actions. The area of Machine Learning (ML) is a core element of AI and helps develop parameters based on past user behaviour patterns and context awareness, to define possible decisions that the user would make, thus allowing technology to predict needs. To be intelligent, a system that is in a changing environment must have the ability to learn. If it can do so, there is no need for the designer to foresee and provide solutions for every possible situation. The technology adapts to patterns observed from collected data (behaviour) to create a "knowledge system" and predict possible scenarios. In 'Introduction to Machine Learning', Alpaydin (2014) says:

> *Machine Learning uses the theory of statistics in building mathematical models, because the core task is making inference from a sample. (Alpaydin, 2014, p. 3)*

It is simply an algorithm, based on past data, to identify patterns and predict futures. The most commonly used example of machine learning in AI today is the text prediction function on mobile messaging applications and search engines, where, based on previous vocabulary, sentence structures used (past data) and a knowledge of syntax in a language (context), the system can predict the next word. Thus machine learning allows technologies to achieve a level of clairvoyance in the decisions that humans make and complete (or suggest) actions without much intervention needed from the user.

Human decision making however, while based on past behaviours and environment context, are also driven by emotion. This element of emotion often leads to irrational choices in decision making that are not based in rational behaviour maintained in past actions. Thus, emotion becomes an essential aspect for (AI) systems to understand and accurately predict user needs. In an article in PR Newswire (2017), C.T.O. of Element Data, Inc. (a decision support software platform), Charles Davis mentioned:

> *Decision making frequently includes an emotional component. Humans make irrational decisions due to extenuating circumstances. (Element Data Acquires BehaviorMatrix, 2017)*

Emotions have a significant impact on perception, decision making, action generation, as well as action execution and control (Bin, Jinrong, Yaojun, Lvwen, & Shuqin, 2017). Steps have been taken in the area of machine learning to gauge emotion in the form of Emotion-Aware (EA) Computing. Emotion-aware computing allows a sensing device to have the ability to recognize the emotional state of humans and gives an appropriate response to these emotions. Emotion-aware computing can offer benefits and play an essential role in an almost limitless range of applications that involve machine learning (Babiker, Faye, Prehn, & Malik, 2015).

Emotions are commonly recognized in three different ways (Bin, et al. 2017). They can be recognized visually by reading facial expressions and gestures of the user with the use of camera sensors that record motion and identify changes that are compared against predetermined parameters to define emotion. The same can be done acoustically through speech recognition and analysis. Changes in tone and pitch act as cues to gauge emotion. The third and more commonly used method of gauging emotion is to record changes in signals of the autonomic nervous system (ANS), where, involuntary changes in the body like pupil dilation, change in heart rate or perspiration can be used to measure emotional condition.

Because of the complexity of emotional expressions, much research still needs to be conducted to understand and explain the mechanisms involved in emotion recognition. There can be more than one reason for a change in ANS, and at this stage, research in the area is limited to merely understand if emotion is positive or negative (Bin, et al. 2017). It is still difficult to gauge the subtleties and complexities of human emotion. Further, the recognition of emotion may not necessarily help predict action. As discussed earlier, actions driven by emotion are sometimes irrational and may not fit into status quo of perceived behaviour patterns that are recognized by EA computing.

As a result of these problems faced, the current Band-Aid solution for limitations in sensing systems is to bridge these shortcomings with the help of the age-old method of input via a platform which requires a central device. But again, as discussed earlier, there needs to be an evolution in the way we interact with AmI to allow it to reach its full potential.

Wearable Technology (WT) in AmI Systems

In their paper, 'From the Internet of Things to Embedded Intelligence', the authors (2013) identified two distinct styles of smart object sensing: Object-centric style and Human-centric style. Smart objects belonging to the object-centric type of sensing, are deployed in the real world and can detect changes in their physical status or/and changes in the surrounding environment. This is the ideal situation that Weiser talks about in his vision of UC. While it is possible to use currently available HCI technologies (objects can be fitted with sensing devices that can read human actions in an environment), for this form of sensing to work, these technologies still have many shortcomings, when it comes to working cohesively outside controlled laboratory environments.

The second (human-centric style of sensing) category focuses on the need of a device that acts as a personal companion that guides the user through a smart environment by acting as an intermediate device that communicates with others. Today this intermediate device has taken the form of Smartphones and Laptops. As discussed earlier, however, these age-old ideas of a personal workstation are losing value in an age where technology is spread around the user, and behave as enablers of stagnation to the evolution of technology becoming invisible. One cannot deny that, given the current stage of sensing technology we are in, the second category is more viable as a solution and there still is a need for an intermediate device to intervene for smoother interaction and better sensing. There is, therefore, a need for a device that replaces the age-old idea of a workstation (used to enter commands) and instead acts as an identifier and translator on the user's behalf, thus allowing for a smoother ubiquitous interaction. Wearable Technology (WT) can play the role of these intermediate devices.

Wearable technology is a form of Assistive technology that is used to increase, maintain, or improve functional capabilities to make the completion of a task easier. It can be broadly defined as any form of technology that that is worn by a user. Today, they most popularly exist in the form of smart device companions (smart watches) and act as mirrors of the smartphones that they are assisting. They consist of a number of sensors that aid functionality of a smartphone and often act as remote controls to the device they assist. This idea of a wearable remote control can be applied to an AmI system where a wearable assists the sensing process to ease the need for sensing capabilities of AmI devices. Thus replacing the need of Ami to rely on a platform for input of user needs.

A combination of the two styles of sensing, where the qualities of environment sensing are still predominant (object-centric) but are helped along in the process of sensing with the introduction of a WT device (human-centric), could lead to a more defined system where one solves the problems of the other. We thus move away from a system where humans interact with technology to achieve a goal and move towards a system where technology interacts with humans (through wearables) and achieve the goal. With the assistance of AmI systems, wearables have the opportunity to disappear in the present culture and enter the realm of the status quo, acting as a 2-way receiver that helps us through our daily lives.

Perceptions & Acceptability of WT

In the US, 31.6 million people used wearables at least once a month in 2015 (eMarketer, & TechCrunch, n.d.). This increased to 44.7 million in 2017 and is projected to reach about 59.5 million by 2021 (almost double in 7 years). There is no doubt that this is a fast-growing market and will only keep growing over its 6.4 billion dollar revenue today (Consumer Technology Association, n.d.).

A major hindrance to the success of smart wearables, however, is found in its poorly designed and limited user interface (UI). The current interaction paradigm of smart wearables simply mimics the age-old UI of touch screen interaction used in phones. In her paper, Yoon says that to justify the adaptation of such UI, some argue that touchscreen-based interaction is familiar to most users. However, smart wearables are physically much smaller (1/5th size of smartphones), and its wearability must be considered for various situations of on-device interaction. She further mentions:

> *The adaptation of touchscreen UI and an awkward relationship with a paired smartphone, has resulted in current smart wearables being hardly considered a fully functional standalone device, but rather a secondary and auxiliary device. (Yoon, Park, & Lee, 2016, p.973)*

Additionally, a wearable, whether used for assistance to a smartphone or in an AmI environment, is more like a piece of clothing than a PC or an appliance, and clothing has been shown to help define identity and supply clues to categorize oneself and others in the culture (Kelly & Gilbert, 2016, p.2866). A significant departure from what is considered normal in current society can lead to the rejection of the technology. Thus, hedonic qualities of technology are likely to play a more influential role in technology adoption, especially in the mobile (moving around) context, than utilitarian qualities. An example of this is shown by Kim K.J. (2016) in his paper comparing smart watch forms. Round screens, despite their perceived negative effect on control, can lead to a higher acceptance of smartwatches by promoting the hedonic (conforming to the accepted) qualities of the device's form & fit. This does not mean that utility is not an important element for these devices. Incorporating hedonic and utilitarian qualities simultaneously into the design of the wearables are extremely important for creating positive first impressions. As a result, manufacturers should continue to strategically plan the enhancement of controllability of round screens, as Samsung has attempted with their rotating bezel, while still focusing on the hedonic qualities of form (Kim, 2016, p.737).

This is where the incorporation of fashion thinking becomes a critical element in the development of the device. If users of wearable technology expect to experience these devices in similar ways as their clothes and accessories, the way to design them should then be inspired by fashion design and fashion practices.

There is also the reaction of human and societal culture that needs to be taken into consideration when developing new forms of interaction for WT. For Example, in their paper on user perceptions of smart glasses, authors Hakkila, Vahabpour, Colly, Vayrynen, & Koskela (2015) show through their findings that the use of smart glasses could have a negative effect on the face-to-face interaction with the people present, and divert the attention away from the social situation. Privacy concerns were also mentioned, mostly in the context of assumptions other people might be drawing about the expected use of the device. Several participants mentioned that they were concerned of the fact that the nearby people would think they are doing something unethical or forbidden with the glass. Complexity & size of products create negative use experiences and result in rejection by users. Small and subtle gestures that go unnoticed, on the other hand, are socially more acceptable.

The papers by Kelly & Gilbert (2016), Hakkila et al. (2015) & Kim (2016) all talk at length about hedonic qualities & the rejection of devices that require actions that do not fit the status quo of society. However, they do not shed light on the interactions with the devices themselves. There is no way to gauge the level of acceptance & comfort that users have in relation to the adoption & use of WT. There is a need to develop an understanding of what users perceive as the future of communicating with their everyday objects to better understand their level of acceptance of WT.

Incorporation of AmI Systems in Everyday Life

As predicted by Weiser over 27 years ago, there has been an emergence in development of computing technology that fits into the environment of the user instead of forcing the user to enter theirs, in the form of AmI systems within smart spaces. While these AmI systems have begun incorporating themselves into various smart spaces, there is great potential for it to influence activities in everyday life, making technology more accessible to people by focusing on environment interaction instead of device interaction. However, the capabilities of these technologies are still limited regarding sensing & prediction of human needs. As a result, there is still a need for human interaction with an interface. Wearable Technology can be a possible answer to replace this platform paradigm, by aiding the sensing process of AmI, thus acting as a key to interact with the environment. The focus then is to understand and develop parameters for the development of WT devices that help AmI reach its full potential and still fit into society seamlessly.

Methodology & Analysis

The methodology is divided into two phases based on the type of data collected and the expected results. This helped segregate data to be analysed so that it can reveal information that answers specific questions raised by the literature. The data was then combined later to form actionable insights. The phases are laid out in this specific order because certain aspects of data collected from previous phase influenced structure and drove discussions in the next phase. A master analysis of all data collected across the entire research period was done at the end of Phase 2, to compare and highlight possible aspects (actionable Insights) that could influence the design of WT within an AmI system.

A sample set of 30 participants across different age groups & socio-economic backgrounds (SEC) was selected for this study. This was done to take into consideration, the bias, that the adoption of technology is slower based on an individual's age and position in society (which was an area missing in previous experiments in literature). The results of the study will thus consider the fact that wearables will eventually surpass early adopters (Rogers E. 2003) and be used by everyone. Additionally, the study includes participants from Europe, Asia and North America to take into consideration different cultural practices across the globe to make the results more universally valid.

PHASE 1

Phase 1 focuses on identifying physical forms & types of interaction that people are (and are not) comfortable with, to gain an understanding of levels of acceptance and perception in regard to WT. The research further helps gain insight into how and why these barriers (or pathways) to acceptance exist and the influence of these devices on perceptions of privacy. Apart from gauging user feelings towards form & function, this data also sheds light on the role of "sensing" in relation to decision making & helps determine ideal methods for the same.

While the literature does cover the values of hedonic qualities as compared to utilitarian qualities, the studies are conducted in controlled environments and information is collected in the form of interviews. It does not test these theories in the real world. Furthermore, past experiments focused on one form of wearable at a time and did not take into consideration other wearable forms & body positions. Using observation as a research tool for phase 1, the experiment proves that along with hedonic qualities of form, (which are proven to be major influencers in literature), hedonic qualities of interaction also play a significant role in user acceptance.

Participants were asked to interact with wearable devices in three spaces (home, work & public) with varying social environments for approximately 20 minutes. Reactions of the participant himself and the people around him were recorded. The same experiment was carried out with three different devices that vary in form, size & placement (varying levels of visibility).

As the use of WT in AmI spaces is still limited, the home & work spaces had prototyped interactions that were staged in order to give the participant an experience of what the technology can be capable of in the near future. An example of this, is the use for Light Dependent Resistors (LDR) to automatically turn the lights on when the participant enters a room and suggest that the WT device was responsible for it.

Devices used for Observation Experiment

Figure 1 Devices used for Phase 1 Observation Experiment: Google Glasses, Apple Watch & Samsung Bluetooth Earphone connected to Google Assistant. Source: http://www.hindi.itemtutorials.eu/video/-n2_RPw6Ytg http://www.businessinsider.com/apple-watch-saves-life-doctor-says-2018-5

A brief interview with participants regarding the features and perceived functions of the device and its effect on the acceptability of the product, was conducted, prior to and post field observations, to note any changes in their answers. Observation as a data collection tool helped remove the possibility of user bias common in interviews (where the interviewee says something because he believes that this is what the interviewer expects) and resolve the discrepancy between what the user says (or believes) and does.

PHASE 1 Analysis

Data Collected from phase 1 was tabulated and compared against 12 parameters to help gauge user acceptance and identify emergent themes & patterns of interaction. Parameters: P1, P4 & P12 were collected from interview notes while the rest were derived from observation. Participants were rated on a scale of 1 to 3 (low, medium, high) for each parameter. The collected data was then tabulated using a bar graph to visually compare findings recorded in each space.

Tabulated Data from Phase 1

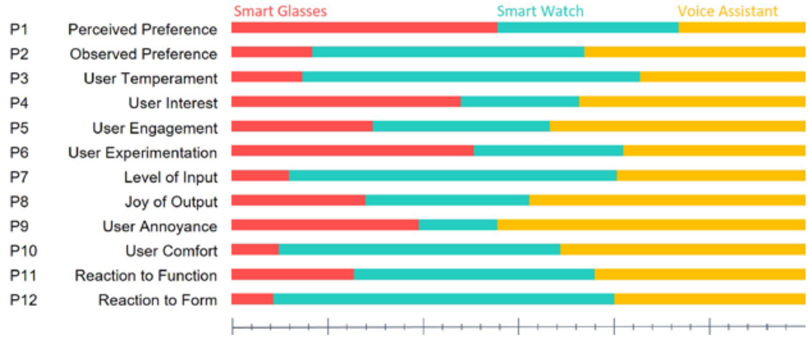

Figure 2 User Observation Analysis in Smart Home Space (1715, Whitaker St., Savannah)

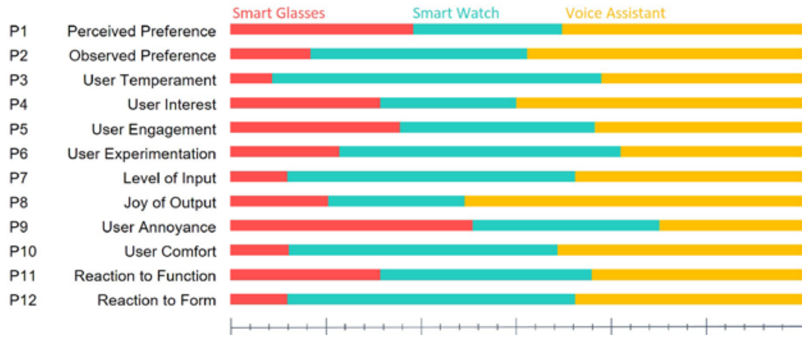

Figure 3 User Observation Analysis in Work Space (Gulfstream Centre for Design, Savannah)

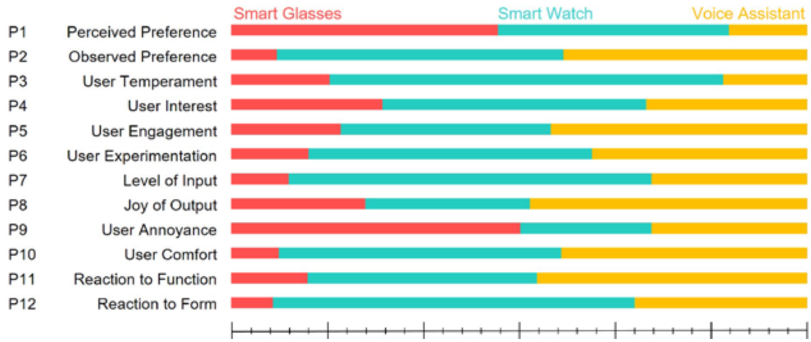

Figure 4 User Observation Analysis in Public Space (Forsyth Park, Savannah)

This research exercise provided insights on two levels. Firstly, the reaction of users and surrounding people revealed information that helped gauge user feelings towards the devices (This was later confirmed by interview responses). Additionally, users performed actions that lead to cues of preferred interaction. Findings from phase 1 were compared to the literature to assess validity of the claims made and cross-check ideal sensing methods perceived by users with those mentioned in the literature to develop an understanding of the best possible fit for the same. In addition to this, findings were also compared to existing methods of boosting adoption to gauge the tipping point at which need of technology outweighs fear of not fitting in.

PHASE 1 Findings

As a starting point, all users grounded the interface and use of these wearables based on previous knowledge of how this kind of technology works. Both the smart watch & voice assistant had shallow learning curves, as interaction with the two was considered more natural. Further analysis of collected data revealed that participants were much more comfortable using wearables in private personal spaces (home & work spaces) as opposed to public spaces. It was observed that using the devices by themselves gave them an opportunity to experiment and make mistakes without anyone judging their actions. Interaction with devices in public spaces were much more conserved.

Most participants perceived the smart glasses as the future of communication technology. However, when using the devices, they were much more inclined to using the smart watch. Furthermore, participants showed a desire to stare at a tangible object (phone) while using WT to root invisible actions in a physical space and showed concern for social image when using the voice assistant as it had no tangible form to interact with. Participants also required a visual feedback that informed them of an action being performed the way they expected it would.

Participants were most comfortable with voice as an input mode (over gesture control) in private spaces even though there were instances where voice input did not work at first attempt. Participants felt that the gestures required as input for WT (smart glasses) were too extravagant and would look ‘weird’ if performed in public. In situations where an action was done without any user input (lights turning on without any specific action), most participants (24) were pleasantly surprised. They were however inquisitive as to how it worked and how the action was activated.

The preference of invisible smart products is relative. While users prefer devices that do not visually affect social interaction, if the technology was completely hidden from others, they seem to get equally insecure. Devices that create a balance between ambient & physical worlds achieve greater success as compared to those that focus more on either one. Furthermore, familiarity of interaction with technology plays a vital role in the acceptance of a new technology.

PHASE 2

Most papers on AmI talk about the possible intervention of AmI for the improvement of activities in daily life. However, there is not much discussion about activities & interactions that AmI could positively affect. Phase 2 provides a glimpse of the everyday rituals that participants undertake, the problems they face, and areas that need an improved interaction experience. Phase 2 also focuses on taking information from findings of Phase 1 to help build possible futures of AmI in collaboration with users by identifying where & why change is needed.

Phase 2 began with the use of participatory photo interview as a tool to observe & record the everyday rituals of participants. The exercise involved participants taking photos of inconveniences they faced in daily activities, using mobile phones, across a span of one week and then writing one line describing it. The same was sent to the researcher via text message as and when the activity occurred. As findings from the previous phase showed that users are much more comfortable using new technologies in closed safe spaces, data collection for this phase was narrowed down to areas in and around the home space.

Photographs are not objective and do not present the objective views of the person taking them; they rather depict a way to see or understand an object or context to offer multi-layered meanings (Collins, H. 2017) allowing the data to be not just a list of problems but a larger picture of an inconvenient situation.

One on one interviews were conducted at the end of the week and the photos taken, act as talking points for discussion of the activities in more detail. This interview first discussed problems faced in everyday life based on photos (the interviewer helped push ideas along, based on findings from previous research) and then moved to a discussion of technologies and sensing methods present in the world today. This was then followed by a discussion about scenarios of the perceivable future of AmI in the next 10 Years that can help improve interactions in daily activities.

The interviews ended with a laddering style discussion that dove deeper into why participants want these activities to change and why they think this sort of change will be effective. Scenarios as a research tool helped create what the participants believe is the future of communicating with their everyday objects.

PHASE 2 Analysis

The analysis of the photos was not limited to composition, content and design. The context within which photographs were produced and published, their historic timeline and how they were presented (Collins, H. 2017) were also taken into consideration. This was done to understand the communicative intentions and, ultimately, the ideologies and cultural meanings embedded in images. This qualitative research technique provided a means of 'getting inside' the user activities and their context. Photo interviewing helped bridge psychological and physical realities & allowed for a combination of visual and verbal language.

Data collected from Interviews compared practices against one another to highlight commonalities, differences and reveal patterns. Data transcribed from interviews along with photos were analysed using the affinity diagramming process to help identify actionable areas of intervention (and spot outliers). The same was compared against the analysis of the photo interviews to create more inductive areas of intervention for AmI in everyday life.

Clustered & mapped findings

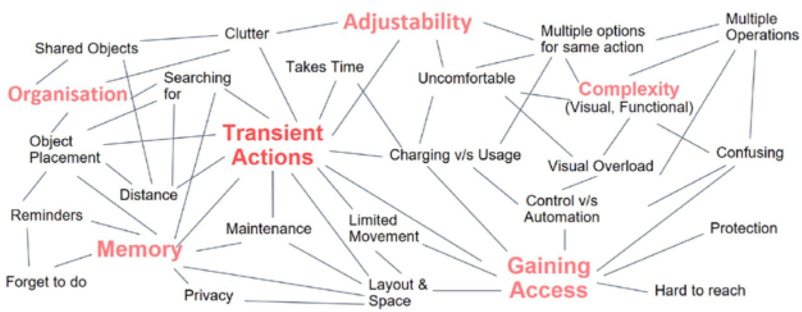

Figure 5 Analysed data from Photo & interview analysis clustered and mapped to identify areas of intervention.

The collected and analysed data helped create a deeper understanding of certain events, behaviours, people, cultures and social forms. It helped to gain an understanding of users' needs for intervention and help gauge their level of comfort with new technologies (based on & combined with inferences from phase 1).

PHASE 2 Findings

Analysis of the data found that problems faced around the home space were almost always the same. The situation in which these inconveniences occurred may have changed across age and location. However, the core issue was common. Users shared the issue of drying utensils after running the dishwasher. A similar problem was seen in participants from India (where dishwashers are not a common household appliance) around the sink in the kitchen.

Mapping and clustering of the data collected through photo analysis and interviews showed that most inconveniences that participants shared were transient actions that were by themselves considered unimportant but were still necessary to accomplish a larger task. An example of this, is the task of using a mobile phone (to make calls) requires the transient actions of the device being charged, walking up to the device, picking it up and going back to where you were previously sitting.

Discussion with participants revealed that these "menial" activities were seen as a hindrance and there was a need for them to be bypassed in order to achieve an ultimate goal faster. Further, most participants did not mind the intervention of technology to make tasks easier provided that it helped reduce steps to a goal.

The mapped data further revealed that these menial activities can be broken down in to four major categories:

- Gaining/Blocking Access to…
- Remembering to do…
- Finding…
- Adjusting/Readjusting…

Conclusions

The aim of this research was to collect data that investigates & proposes ideal dimensions of user interface & experience of wearable devices used, to operate within an ambient intelligence system, and its effect on user acceptability. The study further focused on gaining an understanding of possible areas in daily life where the use of AmI can help make experiences more meaningful. Thus creating guidelines for the eventual development of wearable devices for consumers that help them use AmI systems more effectively, to improve the experience of daily activities, by making human needs the centre of technology.

Results from the above experiments showed that there is a need for better interaction around the home space in order to help users achieve their daily goals by bypassing menial and unnecessary tasks. People are comfortable with the use of ambient intelligence to complete these tasks provided that it does not visually affect their social image and the actions performed are simple, natural and familiar. Furthermore, the devices used to access these AmI systems must weave themselves into the environment and go unnoticed but at the same time are prominent enough to allow users to connect the action they are preforming to these tangible devices. This device must also provide an acceptable form of feedback that informs the user of the task in progress and its completion.

Further Study

This paper provides an initial set of principles that help build a criteria list for the development of wearables to function as communicators within AmI Environments & defines parameters to assist adoption of invisible technologies. However, further research needs to be done in these specific avenues that were highlighted in this paper, with the use of a prototyped device that proves the validity of these findings. This research will focus on ways in which, a more intuitive and natural system of interaction can be created, using wearable technology more effectively in the home environment.

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