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People, Product and Experiences - User Centered Design of Mobile Mixed Reality Applications

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ABSTRACT OF MASTER'S THESIS

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This thesis is based on the newly emerging area of Mobile Mixed Reality (MMR) which is still a futuristic concept for most of the people. According to User Centered Design (UCD) principles, it is important to take potential users into account in pursuing a successful application based on novel technologies, such as mixed reality (MR).

User Experience (UX) refers to users' perceptions and responses that result from the use or anticipated use of a product, system or service. The main purpose and goal of this thesis was to apply UCD and UX approaches in designing MMR applications.

Empirical UCD was performed by using focus groups, questionnaire and scenarios. As a result, it was found that majority of the user needs were pragmatic such as personalization, reliability, relevance and usefulness. I implemented four semi-functional prototypes and five non-functional proofs of concept on MMR based on UCD study results.

UX evaluation was carried by using SUXES, AttrakDiff and Emocard in order to assess as well as improve the UX of the created prototypes and proofs of concept. UX evaluation results shows that concreteness, realizability, personalization, novelty, intuitiveness and usefulness were some of the deciding factors for user expectations and perceptions in regard to MMR.

Studying user expectations is essential for designing products on novel and futuristic technologies such as MMR. Understanding of user expectations can potentially help in the approximation of UX even before the actual implementation and interaction with user. All the prototypes and proof of concept received high grade in terms of use experience and overall acceptance in the UX evaluation results.

This thesis has methodologically validated that products developed based on UCD receive higher acceptance in different UX evaluations.

Keywords: augmented reality, mobile mixed reality, mobile devices, user-centered design, user experience

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"The mediocre teacher tells. The good teacher explains. The superior teacher demonstrates. The great teacher inspires." - William Arthur Ward

Indeed I am very lucky to get such inspiring teachers and role models in last two years of my graduate studies in Finland and Denmark. This list of inspiring teachers is quite long but I would like to take the opportunity to name few of them here. It was my privilege to get an opportunity to work with Professor Kaisa Väänänen-Vainio-Mattila (TUT), who represent the utmost top in the field of Usability and User experience. Many thanks to her for giving permission to write this thesis at one of the best known institute on Human Centered Computing. Her feedback during the different phases of this thesis is invaluable.

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I dedicate this work to my wonderful sisters - Rakhi, Rimple and Mona

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Foreigners often complain of silence, darkness and loneliness in Finland but when you have good family and friends then who could ever complain?

Espoo, June 30, 2011

Amandeep Dhir

Abbreviations and Acronyms

AR	Augmented Reality
AV	Augmented Virtuality
GPS	Global Positioning System
HCI	Human Computer Interaction
HQI	Hedonic Quality Identification
HQS	Hedonic Quality Stimulation
ISO	International Organization for Standardization
LBR	Location Based Reminder
MMR	Mobile Mixed Reality
MR	Mixed Reality
MSA	Measure of Service Adequacy
MSS	Measure of Service Superiority
PC	Personal Computer
PDA	Personal Digital Assistant
PQ	Pragmatic Quality
SIG	Special Interest Group
UCD	User Centered Design
UCSD	User Centered System Design
UED	User Environment Design
UI	User Interface
UX	User Experience
3D	Three Dimensional
2D	Two Dimensional

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Chapter 1

Introduction

This thesis work is carried in collaboration with the Unit of Human Centered Technology (IHTE) at Tampere University of Technology, Department of Computer Science and Engineering - Aalto School of Science, Nokia Research Center, Tampere and Mobile Informatics Lab - Denmark Technical University. The work is primarily assisted and supported by the Devices and Interoperability Ecosystem (DIEM) project at IHTE, Tampere. Finnish Strategic Center for Science (TIVIT) is responsible for coordinating and funding the DIEM research project.

1.1 Background of Mobile Mixed Reality

Mixed reality (MR) concept refers to the convergence of the digital and physical environments where virtual and real objects complement and interact with each other [8]. MR is considered to *"cover the extensive continuum between the two opposite, discrete ends of reality and virtuality"* [49] as shown in Figure 1.1. MR can be practically realized through augmented reality (AR) where real world or physical objects are augmented with digital information and Augmented virtuality(AV) where virtual world is augmented with elements from the real world [7].

AR combines physical and digital information into user's view of the real physical world, giving an immersive view of one environment [66]. AR has the potential to enhance the surrounding environment of the users by providing rich digital information augmented on the physical objects. This information can be in the form of advertisement or resources related to places and situations.

MR is considered as a broader concept of AR, and AR is also part of mixed reality continuum (see Figure 1.1). AR augments the physical world

with digital information and does not create an artificial environment; rather it supplements the physical world [7]. This is the main reason why in this thesis I am not interested in AV but my focus will be on AR part of MR continuum. In this thesis, I view AR from mobile phone context referring AR on mobile devices. The concept and technology of supporting AR by means of mobile devices is called Mobile Mixed Reality (MMR).

Mobile devices particularly smart-phones and tablets such as iPad and Samsung galaxy have become important part of our lives. They are no longer only used for communication but in a broader spectrum that includes social networking, browsing, multimedia and so forth. Gartner Inc [56] is one of the world's largest information technology researches and advisory companies has projected that 54.8 million tablet computers will be sold by 2011 while 417 million smart-phone units were already sold till the third quarter of 2010 [44]. This clearly shows that more and more people are buying them and they have become commodity items. There are several reasons for the increase in consumer adoption rate such as prices of smart-phone and media tablets have come down, devices are affordable, growing need for connectivity and computing all the time, personal computer (PC) like functionality and so forth. These are equipped with different sensors such as Global Positioning System(GPS), camera, video, music, browsing, audio and accelerometer. The

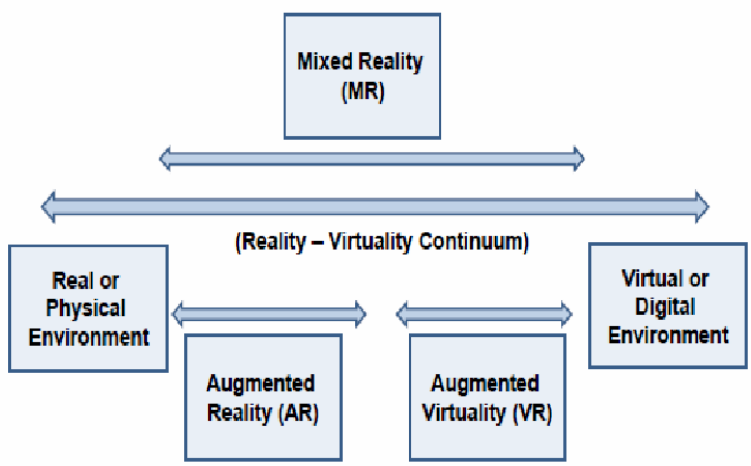

Figure 1.1: Overview of Reality-Virtuality Continuum[49]

widespread growth in the smart-phone market, continuous high speed wireless Internet connectivity and coupled with affordability has made present day mobile phones ubiquitous. These newly connected spaces have enabled the convergence of the digital and physical environments in form of MMR. Mobile phones have expanded AR services so as to cover rich variants of

potential use cases and scenarios. MMR has opened plethora of opportunities for technologist, designers, and business enterprises and above all for the general public.

Mobility has extended the MR services to covers an extensive space of use cases and scenarios. Mobile phones are considered competent equipments for enabling and interacting with the MR objects and services. Magic lense [7] is one of the oldest and widely known interaction paradigms in the MMR domain. It enables its users to access the world through a camera view where the additional information in the form of digital text or symbols is aligned on top of the view. Apart from this, data glasses and other head-mounted displays are also talked in the MR domain but there are out of the scope of this thesis as I am interested only in the mobile phone based MR i.e. MMR.

1.2 Research Motivation

Last decade has witnessed a growing interest towards the MMR solutions where researchers, gaming and service companies are interested in exploring the MMR experiences. MMR possess a huge market potential that is why many business houses are approaching this association of virtual - physical world with several different business models in order to tap this attractive opportunity [23, 59] . Personalized shopping, social gaming, and augmented events can be named as few of its business prospects [67]. Business value of MMR can only be practically realized if the needs and expectations of the prospective users of MMR are understood.

The potential use cases for MMR concept range from urgent, safety critical and demanding to leisure and entertainment oriented. Due to this reason it becomes very important to understand the context in which user would like to use this service. User Centered Design (UCD) methodology should be employed in order to understand the requirements of the users, their tasks and use context of this technology. There are some studies that have been conducted lately like Olsson et al. [53] and Vaittinen et al. [65]. Both these papers tried to understand users' expectations and needs for MMR services. Olsson et al. [53] has performed user studies on collecting user needs and expectations from MMR using focus group discussions having different use cases of MMR using scenarios. Vaittinen et al. [65] conducted diary studies for gathering user needs in context to MMR. However both these studies are limited only to understand user expectations for MMR services. In this thesis, I aim to extend this existing work by following UCD methodology in creating potential MMR concepts based on user needs and expectations. Furthermore I aim to evaluate UX of these created MMR concepts by using

different available UX evaluation methods.

MMR can provide rich, pleasing, enjoyable and positively surprising experiences to its users. However, this research topic has not been much explored yet. So far the research and development on MR technologies is mostly focused on creating enabling technologies such as display and other output devices [49], algorithms for positioning and tracking real world objects [7]. I believe that despite this extensive research on MR enabling technologies, research community is still finding potential scenarios and use cases for MR. Furthermore, there are a lack of understanding on users' perspectives and requirements for MR. It becomes even more important because MR domain is in such a level of maturity that end-user applications can start mushrooming.

UX and adoption perspective of MMR have been less discussed. Furthermore, user research has mostly been focused on finding and correcting usability issues [16, 62]. Understanding user expectations is important not only for designing usable products but also for designing products based on novel and futuristic technologies like MMR. Furthermore, studying user expectations can potentially help in the approximation of the UX before practically realizing applications that users can test and interact with. Heikkinen et al. [28] has successfully proved this argument that studying user expectations can help in designing UX. For developing successful products for a futuristic technology like MMR, it is important to identify the expectations of the users' from MMR as these expectations later define the UX [53]. Clearly, here is a need to study UX of MMR with a holistic approach, considering subjective and temporal nature. Development of newer concepts and practices for creating playful experiences in this domain should be explored. In this thesis, I aim to develop different set of semi-functional prototypes and proofs of concept for the MMR.

Internet and GPS enabled mobile phones can provide its users with a brand new type of communication that mixes rich communication of the digital space with the physical world. This hybrid space raises several questions on the trust, privacy, acceptance and so forth. However, these topics are out of the scope of this thesis work but implicitly I kept all these challenges in mind while designing MMR prototypes and proofs of concept.

With respect to the thesis title, the keyword *"People"* refers to the social aspect of MMR. It is my assumption that having factor of social engagement in a MMR application can help in user adoption of MMR overall. *"Design"* refers to the potential design of MMR application that enhances the experience of MMR users and provides engaging effect during interaction. *"Experience"* refers to the feeling of pleasure, beauty and arousal while using MMR application. UX of MMR application should be designed in order to give pleasing emotional response to its users. Keeping these different

approaches in mind, my aim is to develop MMR prototypes and proofs of concept which take into consideration social, design and experience aspects of any interaction but this is only possible if the application is designed by employing UCD and later tested for evaluating UX to enhance its holistic view.

1.3 Research Questions and Objectives

In this thesis, I focus on investigating the user needs and expectations from MMR technology similar to Olsson et al. [53] and Vaittinen et al. [65]. The concept of MMR is new for the majority of mobile users so it is important to develop this kind of service from users' point of view so that the service can be adopted by the masses. Therefore the main objective of this thesis is to examine the following statement -

"To design potential MMR concepts though User Centered Design(UCD) methodology and evaluate their User Experience(UX)" This objective is further concretized by research questions below

- *What are the users' needs and expectations to this technology?*
- *What kind of MMR concepts seem most appealing to the users?*
- *What methods are the most suitable for evaluating UX of the designed MMR prototypes and proofs of concept?*
- *What are the challenges of creating concepts based on new technologies?*

The objective related to the first question is to investigate the users' needs in regard to MMR as an overall concept. It will help in getting the end-users' perspective to the development of MMR prototypes and proofs of concept. The second question is addressed by developing new MMR concepts in form of prototypes and proofs of concept and evaluate users' appeal towards them. Regarding the third question, the objective is to apply various UX evaluation metrics to create a holistic set of evaluations, with which to assess the overall UX of the designed MMR prototypes and proofs of concept. The last question is addressed by identifying challenges in creating concepts based on new technologies, such as MMR.

The final outcome of this thesis project is to develop semi-functional MMR prototypes and proofs of concept based on the findings of UCD model. Different methods for evaluating UX are investigated and applied using these developed prototypes and proofs of concept. This work will serve as an example for developing user centered MMR solutions in future for the growing mobile phone industry.

1.4 Research Approach and Methodology

The study is both constructive and explorative by nature where on one hand, creating design and developing semi-functional prototypes and proofs of concept represents a constructive approach, and on the other hand, user studies tries to examine and explain phenomena related to UX and user needs related to the MMR concept.

UCD methodology involving 15 test participants is used to answer some of the questions demonstrated in the Section 1.3. This required extensive user research that includes identifying user needs, users' current mobile activities, patterns, and technology-related suspicions if any. However, my end goal is to create semi-functional prototypes and proofs of concept that take all above mentioned issues into account and finally evaluate them with representatives of potential end-users.

Reviewing of AR literature and applications (see Chapter4) is performed using heuristics; extensive user research (see Chapter 5) and available literature on the MMR and AR are the starting point for our prototype design process. Olsson et al. [53] and Vaittinen et al. [65] are helpful because of their similar research approach and focus on UX, the study methodology presented in both these papers acted as a potential guiding source in my user research phase.

Four semi-functional prototypes and five proofs of concept are created on MMR after performing empirical UCD. Later, they are evaluated using SUXES, AttrakDiff and Emocard UX evaluation methods (see Chapter 6).

1.5 Contributions

I carried out all the empirical parts of this thesis except the creation of affinity diagram in which two other colleagues helped me in performing analysis. The planning of different phases of this empirical study is done in collaboration with instructors; however I have been the most *dominant* there as well.

The main contributions of this thesis work are implementing four semi-functional prototypes and five proofs of concept for MMR based on users' needs and expectation, and evaluating UX of these prototypes and proofs of concept by adapting three existing UX evaluation methods.

1.6 Thesis Outline

So far, the introduction has unveiled the background of MMR, research motivation, research questions and objectives for this study. The research approach, methodology and contribution of the author has been presented.

Chapter 2 provides a theoretical view on the UCD methodology in designing products. Different UCD research methods for user data gathering and user data analysis are discussed and presented. Main emphasis is given on those research methods that are actually practiced during the empirical phase of the UCD, reported in Chapter 5

Chapter 3 presents the concept of UX and its role in designing products. Different UX frameworks and background theories are discussed. In the end, need for evaluating UX of any product is presented and three different UX evaluation methods are discussed. The evaluation part of UX is reported in Chapter 6.

The empirical part of the thesis starts from Chapter 4
Chapter 4 shortly presents the review of Augmented Reality (AR) literature and applications. A handful of important applications are reviewed and a feature triangle is created to better understand their functionalities, features and contributions. Finally the summary of the requirements for any future MMR application is presented.

Chapter 5 covers the empirical part of UCD methodology and its associated research process in the thesis work. The section outlines different phases such as goals behind the study, UCD methodology, and analysis of the gathered data and finally the results of practicing UCD.

Chapter 6 describes the UX evaluation of MMR prototypes and proofs of concept by employing three different UX evaluation methods namely AttrakDiff, SUXES and Emocard. First the created prototypes and concepts are presented and study methodology is described. Finally the results are drawn from the evaluation part of UX.

Chapter 7 presents the discussion on study results and its contribution. This covers relevance to the various claims made in the theoretical and empirical chapters of this thesis. Later, the research questions defined in the beginning of this thesis are answered. Finally the validity and reliability of the presented study is described.

In Chapter 8 brief summary of the results from this thesis is presented, importance and novelty of the different empirical parts are discussed. Finally important ideas for future work are described.

Chapter 2

User Centered Design Methodology

This chapter presents the background and definition of UCD methodology and discusses different research methods relevant for this thesis. This involves, for example, different UCD research methods covering data gathering, data analysis and evaluation. Emphasis is given on explaining those research methods that have been used in this thesis. In the end of this chapter, UCD is summarized. The empirical part of UCD is reported in Chapter 5.

2.1 Defining User Centered Design

User Centered Design (UCD) is a three decade old phenomenon that came into existence in 1986 when Norman and Draper [52] coined the concept of User Centered System Design (UCSD). They discussed the role of having good understanding about the potential users of any product but without actively involving them in the process. Later in 1996, Karat et al. [38] emphasized the role of UCD as an *"iterative process whose goal is the development of usable systems, achieved through involvement of potential users of a system in system design"*. UCD is a development process where users are actively involved throughout the development process already from the beginning of the product design. There are several benefits of having active user involvement such that it helps in getting clear understanding of the user needs and requirements. UCD is not only about active user involvement but it is a multidisciplinary methodology to interactive designing and evaluation. [68]

UCD can be defined in many different ways depending upon the context of use and nature of the product. UCD involves participation of the users in

the design process of the product development. International Organization for Standardization(ISO) [1] is a worldwide trusted organization responsible for framing international standards. These standards are considered credible as they are composed by the board of internationally renowned researchers and practitioners.

ISO 13407 [4] is a standard that describes the process of carrying UCD. It defines four principles of UCD -

1. Actively involving users and clearly understanding their tasks and requirements.
2. Iterative design that ensures users needs and requirements are properly considered in the product design.
3. Multidisciplinary design ensures that human aspects of the design are addressed.
4. Appropriate allocation of function between users and technology ensures that suitable mapping exists between system and user.

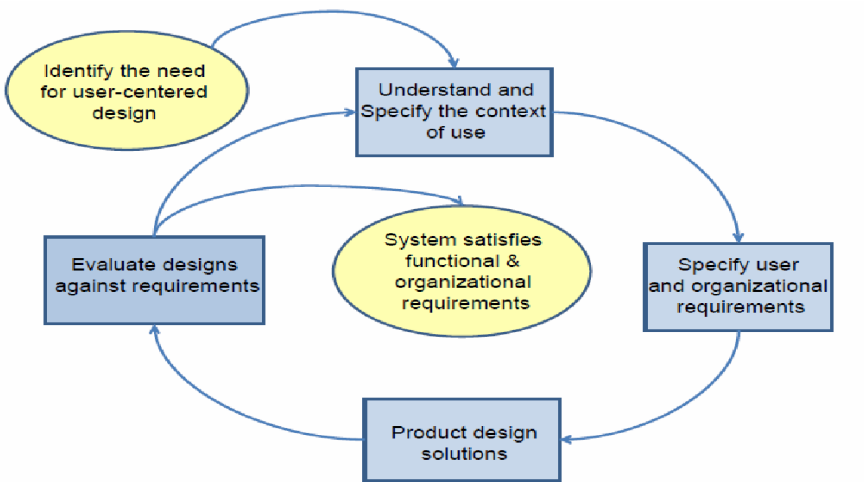

Figure 2.1: ISO 13407 UCD process model [4]

ISO 13407 defines iterative UCD methodology in four stages (see Figure 2.1). The four stage iterative process is triggered when the need for the UCD is identified.

1. Understand and specify the context of use (users' insights, user goals, tasks, behavior, working environment)

[1] http://www.iso.org/iso/home.html

2. Specify user and organizational requirements.

3. Product is designed based on the gathered information and existing HCI knowledge

4. Evaluate designs against the user needs and requirements.

Gulliksen et al. [22] proposed the definition for UCSD along with 12 key principles for the adoption of user centered development process. Previously, UCSD had no one agreed definition due to which misconceptions about the effectiveness of UCSD were present. UCSD is a *"process of emphasizing usability throughout the development process and further throughout the system life cycle"* [22]. The 12 principles for UCSD adoption are user focus, active user involvement, evolutionary development(system developed should be iterative and incremental), simple design representation for users, early and continuous prototyping, evaluate use in context, explicit and conscious design, multidisciplinary teams, involvement of usability experts, holistic design covering all aspects of future use, local process customization of UCSD, and user-centered attitude.

The benefits of involving users in every phase of the design process are usability of the system is enhanced and unusable designs can be replaced at initial stages of the development. If a product designer targets to design a product that matches exactly the user needs and usage purposes then he should first understand the user requirements, expectations and actions.

ISO 13407 provides only partial guidance for performing different phases of the UCD but in practice there are several research methods for practically realizing UCD methodology. I presented an overview of UCD research methods (see Section 2.2) with emphasis on data gathering (see Section 2.3) and qualitative data analysis methods (see Section 2.4).

2.2 UCD Research Methods

In this section, different UCD research methods for data collection and data analysis are introduced. Emphasis has been given to those qualitative research methods that are practiced during the empirical UCD study (see Section 5). ISO 13407 process model have been used as a guiding source in the research process.

The choice making of different UCD research methods is dependent on research context and type of product to be developed. Furthermore, UCD research methods are dependent on the type of information to be gathered. Users' data is collected in the different phases of the UCD methodology. In

the first phase, users' needs, requirements and information related to their cultural settings are obtained in order to understand their expectations towards a novel technology like MMR. This kind of collected information can potentially help in creating new design or update the existing ones. Second phase is performed more actively, where users are interviewed, observed, testing so as to gather knowledge that helps in making design better and proceed with the product development. Third phase deals with the post designing process; user tests the design and expresses opinions. This data gathered acts as a guideline for design iterations and finalizing of the design. [32]

Qualitative methods include open interviews, observation, focus groups and open ended questionnaires filled by the participants. Qualitative methods are useful in subjectively studying user acceptance and expectations of any technology or concept. Furthermore, qualitative methods are competent in understanding and eliciting of user requirements and motivations in the potential design of any future product. [36]

Quantitative methods include closed response questionnaire where participants are given pre defined options for entering their responses. Quantitative methods are used in objectively assessing the user acceptance and expectations of any technology or concept. Data collected using quantitative and qualitative methods require different methods for its analysis. [36]

All research methods have some pros and cons so completely relying only on one method can even prove risky. Furthermore, this gives only a one dimensional view on the topic as every technique can give insight into some particular aspect of the area under study. To solve these problems, I followed the triangulation principle [33] in the empirical part of the UCD study reported in Chapter 5. Triangulation is also referred as mixed research and it can be defined as an art of combining different research methods in order to study one specific area. This means that research methods can overlap each other at times, even contradict or can even complement each other. This phenomenon can provide a balancing effect on the overall study that will enable a richer, reliable and valid study. [33]

2.3 Data Gathering Methods

Data gathering methods are crucial for the success of the UCD methodology, practiced in the development of any new concept, product or service. For designing a product, first a product designer needs to identify the requirements for the product, users' motivations and needs and locate gaps in the existing or similar products in the market. UCD methodology is based on the users' data but from where this user data comes from? In order to gather user re-

quirements, motivation, expectations and habits, appropriate data gathering research methods needs to be employed. The process of gathering user data is performed through field studies which is also called ethnography. [32]

2.3.1 Focus Group

Focus groups are specifically designed discussions on a certain area having 3-8 participants. The participants represent the specific group of people having certain valuable characteristics for the area or product under development. One or more persons act as a moderator during the discussions that steer the conversation rather than participating. The sessions make use of different stimuli agents such as story boards, visuals, pictures, use cases and so on. The conversation skills of the moderator and preparation for the event affect the outcome of the sessions. Focus group can be purely interview based or having mixed approach where moderator and/or facilitator steer discussions and note down important observations. [60]

Focus groups can take place in laboratory kind of settings (see Figure 2.2) or at outside places like cafeteria, home and social gatherings. Focus groups are categorized as a qualitative way of collecting data. It is useful in those situations where a product designer is trying to understand and identify the complex user needs before the actual product development. Kitzinger [39] stated that data received from focus groups is reliable, authentic and empirical but it helps in forming hypothesis on the area under study. Krueger and Casey [41] stated the goals of performing focus group are - *"to listen and gather information. It is a better way to understand how people feel or think about an issue, product or service"*. The emergences of focus groups have started in the early 1930's when social scientists started searching for an alternative to the individual interviews. The interview sessions at those times were fully structured so results were seen as biased due to the for-judged ideas of the interviewer. To solve this problem, in 1940's first focus groups were conducted in order to shift the focus from interviewer to the interviewee. Currently, focus groups are known to be one of the common research tool used by UCD practitioners, market researchers and scientists. They are useful in getting *"under the skin"* of the participants thinking and feelings. [41]

During this thesis, I performed four focus groups where 15 participants are interviewed in group settings. I acted as a moderator and aim was to collect qualitative data in form of subjective opinions, thought and suggestions of the participants (see Section 5.2).

Figure 2.2: (a) Outside of a room where I performed focus group discussions (b) Inside view of the same room showing focus group arrangement

2.3.2 Questionnaire

Questionnaire is a commonly used technique in empirical research for quickly gathering data from a large user base. Questionnaires can be open ended or closed as it depends upon the type of data to be collected. Data collected using closed questionnaire can be analyzed using statistical method while open ended questionnaire are analyzed using qualitative research methods. Questionnaire can be implemented in several ways like distributing paper copies, sending electronic copies through email and internet. [19]

Questionnaire can also be used to complement the existing research methods for example, factors and issues that are not obvious from interviews, group sessions and observation. Questionnaire is one of the commonly employed data collection methods in user research but for getting optimum results it is important to consider their reliability and validity in context to the product or service under question. Designers are required to put considerable amount of effort in designing the questionnaire in order to benefit from them. [19]

During this thesis, I used questionnaire as a means to collect quantitative data on participants' technical orientation and background. Furthermore, I used questionnaire for assessing the user acceptance and expectations of MMR. Both these questionnaire are included in the focus group sessions so all 15 participants answered these questionnaire during the focus discussions (see Section 5.2.2).

2.3.3 Scenarios

Scenarios are not purely user data gathering method but works on the top of gathered user data. Scenarios are commonly used research method for getting more out of the other methods by providing the informant (user) stimuli to react to. Scenarios are designed in order to present and situate particular solutions, present alternative solutions and locate potential problems. Scenarios are used by product designers for anchoring specific work/use situations in any iterative UCD methodology. Scenarios are abstract constructors with a purpose and stimulus agent for the participants. Scenarios are designed keeping in mind the knowledge about actor, environment, culture and other specific instances of product or concept under development. Scenarios in form of storyboard, Power-point or even on an ordinary paper are used to present a situation, futuristic technology or concept so that participants can feel an immersive view of the use case. Scenarios can also be adapted with other UCD techniques like focus group, prototyping or ideation. [11]

I used scenarios as additional methodological tool for data gathering. I created three scenarios which are tested with users during focus group discussions (see Section 5.2.2)

2.4 Qualitative Data Analysis Methods

The collected data stands meaningless for product designers until certain meaningful patterns are created from the gathered user data. After collecting data using various qualitative method like interviews, focus groups, observations and quantitative method such as survey and questionnaire, it is important to choose a correct method for data analysis. Finding the implications for a potential design and interpreting user data meaningfully requires effort, time and careful examining. There are many different ways to structure and classify user data for example on the basis of importance, applicability or appeal. [61]

The choice of selecting an appropriate method for data analysis is dependent upon the chosen data gathering method in the study. For example if the study involve quantitative data then it can be summarized and analyzed using different mathematical or statistical methods but if study utilizes qualitative research methods then generalization is performed by raising level of abstraction. In such cases, the goal of the performing data analysis is to locate patterns, problems, issues and motives within the studied user group. [3]

In case of qualitative data analysis, the abstraction level depends on sev-

eral factors such as amount of user data, kind of product to be designed and extent of the study. Making decision about the level of abstraction for any data analysis process requires both skills and experience. Moreover, it requires care interpretation of the gathered data so that results are useful even for the later processes. [10]

2.4.1 Affinity Diagram

Focus interview process extracts data about the users, primarily their needs and expectations towards a technology, concept or product. However, only one or two team member talking to users is insufficient because whole design team needs to understand as what has happened with the users. It becomes even more important when large teams are involved in designing a new product. The whole team should understand the implications for the design as different people have different perspectives so they can potentially see different implications in the data. Affinity diagram aims to bring the whole team together, share the collected data and develop interpretations upon common understanding. [30]

Affinity diagram is also called wall due to the use of wall or wall like board in processing observation notes. Affinity diagram is a bottom up approach as ordering knowledge and information processing is performed by first using base elements. All individual observation in form of post-its are first specified in great details and later these post-its are linked together to form a larger groups. These groups are joined together and even at many levels, until a complete high level system is formed (See Figure 2.3). [10]

Affinity diagram is an efficient tool for analyzing large amount of qualitative data. Affinity diagram strives to project an underlying structure of work across different users without losing individual variation while the results can be reused by future projects. Affinity diagram helps in mapping different insights and issues across all types of users into a wall like, hierarchical diagram in order to locate the scope of the problem. The affinity diagram is based on user notes and observations represent different issues, user needs, preferences and problems. [9] Affinity diagrams enables product designers in deciding what matters in the concept, act as guiding source, helps in structuring a logical response and taking appropriate business actions and delivery techniques.[9]

The whole or a subset of design team sit together and goes through the written notes, observations and transcript. The interpreted design ideas and questions are written over the post-it notes. Teams later organize these post-its into clusters on a wall. Created clusters are named and collected into higher level grouping. Teams are recommended to think creatively and deeply

Figure 2.3: (a) Post-it notes in Affinity Diagram (b) Post-its are arranged in three level hierarchies

about data and avoid using any predefined categories to cluster post-its. Affinity diagram involves group interpretation which allows other members of design team to be brought into conversation. Team members who were not present during interview sessions can provide their unique viewpoints on the data. [30]

I praticed affinity diagram with two other friends for analysing the user data collected during the empirical part of UCD study (see Section 5.2.3). The results of performing affinity diagram is reported in Chapter 5 (see Section 5.3)

2.5 Concept Creation and Evaluation

After performing the data analysis, design teams often have abundance of ideas of varying details. These results and ideas must be transformed into high quality concepts. The process of concept creation, visualization and evaluation is an important part of UCD methodology. Ideas are created and transformed into concepts; later concepts are combined into product concept candidate. There are different ways of visualizing those concept candidates namely - scenarios, storyboards, paper and functional prototypes. [54] Prototyping is a useful technique for representing potential use cases. It is recommended to use prototyping in the early phases of the design so as to evaluate the feasibility of the purposed design but prototyping can also be used in the later phases to evaluate the functionalities of the design.

In this thesis, I used paper prototyping after getting results from affinity diagram analysis (see Section 5.3). After visualizing the concepts candidates, validation is performed using different evaluation methods as discussed.

Figure 2.4: (a) Example of Paper prototype for mobile phone (b) Example of a scenario used during this thesis

User Environment Design User Environment Design (UED) is a technique for visualizing the overall layout of new system. Beyer and Holtzblatt [10] stated that *"UED shows the floor plan for the new system"*. UED depicts all the components of the system, navigation to different components and what kinds of functionalities are supported by this new system. Furthermore, UED helps in conceiving a high level view of the new system so as to make its possible extension easy and comfortable. UED is essential for the product designers due to several reasons [10] -

1. Design team can make sure that design of the product is right for its users.
2. Through UED, designers can communicate their work to other engineering teams and senior management of their company.
3. Designers can easily decide on how and when to introduce new features for the new product.
4. UED keeps the new product coherent for the users but without making any compromises on ease of product implementation and delivery.

In this thesis, I practiced UED before the actual implementing of the semi-functional prototypes (see Section 6.2) and non-functional proofs of concept

(see Section 6.3) on MMR. As this thesis is an individual work so I acted both as a designer and decision makers while practising UED.

2.5.1 Evaluation Methods

By evaluation, I refer to evaluation of created concepts or existing design. Evaluation can also be interpreted as validation of the created concepts. Evaluation of the newly creating concepts or existing applications can provide rich information that helps designers in improving or creating product designs. Concepts can be evaluated in two ways - First, expert evaluation involving some expert or other researchers for example Heuristics. Second, evaluation performed by potential user in a formal or informal testing. There are several evaluation methods involving experts or users but in this thesis I have focused only three methods namely- wizard of oz, thinking aloud and heuristics. [50] Feedback received from different evaluation sessions is redirected to the concept creation phase where concepts are improved. This improvement and evaluation are performed in form of an iterative cycle [54].

2.5.1.1 Think-aloud

Think-aloud testing is employed for gaining the user feedback on the created concepts. Think-aloud means test participants are asked to *"think-aloud in order to verbalize their thoughts"* [31] while performing the testing with the concepts. Furthermore, participants are asked to express their opinion freely on the encountered problems, motivation, expectations and level of satisfaction while using the concept or prototype [31]. In this thesis, I used think-aloud evaluation in performing focus group (see Section 5.2) where participants are asked to express opinion based on given storyline and scenarios. Furthermore, I used think-aloud evaluation for testing paper and functional prototype testing. However prototype based testing is not reported separately instead based on the testing results, MMR prototypes and proofs of concept are improved and reported in Section 6.2 and 6.3. The reason behind not reporting prototype based testing separately is that the majority of findings from prototype testing sessions are related to the usability while the focus of this thesis is on concept development and UX.

2.5.1.2 Wizard of Oz

Wizard of Oz is rapid prototyping technique for simulating a product that requires new technology or is costly in implementation. Wizard of Oz enables designers to test the system under development for knowing its feasibility

and user response without actually investing into its implementation. A human wizard simulates the machine learning or the system's intelligence and interacts with the user through some kind of mock interface. It is an efficient method for establishing the viability of some futuristic technology or concept. [69]

In this thesis, I combined wizard of oz with paper prototype based testing. However prototype based testing is not reported separately (see Section 2.5.1.1 for explanation).

2.5.1.3 Heuristics

Heuristics evaluation is commonly used practice for evaluating designs. Heuristics is an expert evaluation technique as researchers itself act as dummy user and evaluates the design by using a list of predefined heuristic rules. However, applying Heuristics in practice can also be risky because its efficiency depends upon the experience an practice of the participating researchers. Heuristics mainly deals with flaws related to usability and consistency of the presented information. [31] In this thesis, I used heuristics evaluation method in creating feature triangle(see Section 4.2) and summary of requirements for any future MMR application(see Section 4.3) by reviewing a handful of existing MMR applications (see Section 4.1) in order to locate the design drivers for my MMR prototypes and proofs of concept.

2.6 Summary of UCD

The UCD methodology strives to involve the potential users in the early stages of the any product development. UCD is an efficient approach as user needs and expectations are fully utilized into the product design. There are different kinds of practical research methods, some of them meant for gathering user data, some of them for evaluating design decisions, and some for helping in product design. On one hand UCD is very useful for any product development but on the other hand it is challenging to perform especially designing a product based on new technologies.

Beyer and Holtzblatt [10] stated that *"Understanding the customer is difficult. Design teams need extensive, detailed information about customers. Building any system based on customer data is difficult as it requires series of conceptual leaps to go from facts about customer to a system design"*. Furthermore, designing user centered products on futuristic technology using UCD can be challenging for product designer. It becomes difficult for the users themselves to define future needs without interacting with a functional

prototype. Users do not trust those concepts which appear too futuristic. The attitude of users easily turns suspicious if the concept appears not feasible from technology point of view.

Keeping these concerns into mind, I cautiously designed the overall UCD study methodology where all micro and macro level details of UCD study are rigorously explored and consulted with the instructors of this thesis work before actually conducting the empirical phase of the UCD methodology (see Chapter 5). Furthermore, I made semi-functional prototypes and non-functional proofs of concepts for MMR keeping in mind the futuristic looking nature of MMR. This enabled me in getting authentic and real user inputs on the MMR application design. UCD is considered essential for designing usable and high quality products but in order to achieve this goal, I require more than just UCD. Product designers are required to gain a subjective and holistic view of user needs and resulting experience from the interaction with the product they are going to design.

The biggest challenges for the product designers are *"what kind of experience could be evoked by a particular design"*, *"what kind of experiences would be desired"* and *"how to design user experience (UX) in general"*. To answer these questions, I presented the definition of UX, theories and models for designing UX and methods for evaluating UX of MMR prototypes and proofs of concept in Chapter 3. Furthermore evaluation part of the UX has been presented with enough details in Chapter 6.

Chapter 3

User Experience

This chapter provides an overview of different frameworks, theories and models for UX. The review of existing frameworks and theories is essential in building understanding on what is UX and why it is needed. The chapter begins with an overview at Human-Computer Interaction (HCI) life cycle as how HCI field has emerged from early 1980's to the present day. The emphasis is given on the events that lead to the emergence of the User experience (UX) as a field of study. After presenting the UX frameworks and its background theories, I presented the need for evaluating UX in Section 3.4. Three methods for evaluating UX are presented that are utilized in this thesis. Furthermore, the evaluation studies on the UX evaluation methods is presented in the Chapter 6.

3.1 Life cycle of HCI and UX

HCI emerged about three decades ago due to the expanding PC market in 1980's. Personal computers were widely adopted by the users and this lead to increase in the sale of PC software's. This paved the way for HCI because in majority of software installations, there was a need for customer training and installations. HCI tried to make these early installations usable enough so that there would be no need for additional help and training. HCI has now reached new domains which was completely new for the majority, some two decades ago. [42]

Usability research is one of the main contributing factors for the growth of HCI. In the past 20 years, usability research has lead to improved design and pleasant user interfaces. In the early days of HCI, usability was the primary focus area and this trend continued till late 90's. With the beginning of the millennium, there has been sudden shift of the HCI community towards the

UX [42]. Kuutti [42] stated that *"there was a vacuum for a new concept on which people can discuss"*. Furthermore, he stated that *"traditional methods such as usability design and testing were getting mature day by day in the industry"*. This very need lead to the emergence of UX. Law et al. [45] states that the reason behind the extensive interest in UX can be attributed to the fact that practitioners and researchers were well aware with the limitations of the traditional usability frameworks. The former focuses on user performance and cognition while latter signifies aesthetic and emotional aspects of user interaction with the product or service. Jordan [34] stated that the usability has improved the products to a great deal due to which expectations of the users have increased. A good usable product is not enough for users now and they demand more - a pleasurable experience.

Jordan [34] presented three phase road-map of how UX emerged in the field of HCI (see Figure 3.1) starting in the beginning of 1980's and ending by the new millennium. The first phase consists of early 1980's when HCI specialists were completely ignored as companies viewed technology aspects as more productive compared to the human factors. The second phase started in early 1990's when HCI specialists get some acknowledgment as they were asked to design interfaces for the already development products. The third phase started with the beginning of new millennium when more and more HCI specialists were hired, usability became essential for any type of product and UCD methodology became part of agile product development. Jordan [34] defined three phases in 2000 and I felt there is a need to adapt this road-map in order to cover the recent happening in HCI. In the Figure 3.1 in

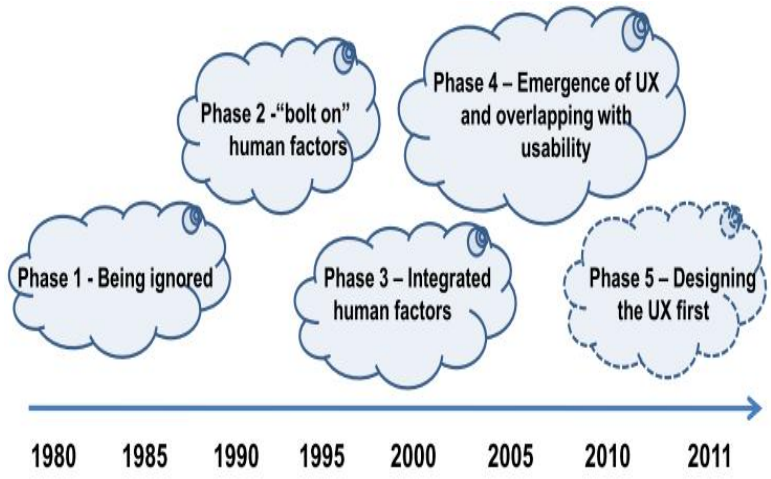

Figure 3.1: Adapted model of development towards designing UX [34]

addition to Jordan's [34] three phases, there are two more phases added by

me. The fourth phase is *"Emergence of UX and overlapping with usability"*. It describes that the UX has emerged but confusions exits such as what is the definition of UX, how to study it, how to evaluate it and so on. UX is often overlapped with traditional usability and even practitioners often use both these terms as synonyms. The fifth phase started in the end of last decade which is *"Designing the UX first"* and it is still in progress. It signifies that although both UX practitioners and researchers realize the need for having designing UX first but confusions still prevail in agreeing on particular methods that can potential help designers in designing UX. The new challenge will be to clearly state *What is UX and what is not? How to design products that evoke positive emotions and pleasurable UX for users?*

3.2 What is User Experience?

In recent past, UX has received enough limelight that it has become important research area in HCI. In-spite of having gained so much importance there still is no common understanding on the precise definition for UX. Many different conferences, workshops, special interest groups(SIGs) and panels have been organized in order to achieve this goal but still the goal of having one common definition for UX is not accomplished yet. [45]

Hassenzahl and Tractinsky [26] has titled UX as a strange concept that has been readily accepted by HCI. Both practitioners and researchers are affected by this strange phenomenon. Practitioners and researchers have stressed that even though large number of theories, facts and concepts have been studied in context to UX but still there is an absence of a common theoretical framework for UX. Forlizzi and Battarbee [20] coined UX as a term having several meanings ranging from aesthetic aspects such as emotions, beauty and pleasure to traditional usability aspects that emphasize on task performance and learn-ability.

There are several reasons for not having a universal definition of UX. First, UX consists of broad range of topics such as emotional, hedonic and aesthetic objects that are dynamic and confusing at the same time. Practitioners often include and exclude these objects depending upon their interest and area of working. Second, the term UX is so adaptable that it fits very easily to different cultures and disciplines. Third, UX research is fragmented and complicated due to the presence of different theoretical models having diverse focus on factors like emotions, hedonic, pleasure, experience and value. [45]

Law et al. [45] carried a survey of 275 UX researchers and practitioners in order to collect views on UX so as to understand, scope and define the UX concept. It was found that UX is seen as dynamic, subjective and

context dependent. Law et al. [45] called *"UX as an individual phenomena rather than social that emerge when user interacts with the product, service or system"*. Furthermore, it was found that there are several concepts that are often confused with UX such as brand experience, product experience and service experience. To clarify these difference between these concepts Law et al. [45] recommended that *"UX to be scoped to products, systems, services, and objects that a person interacts with through a user interface"* (see Figure 3.2) Law et al. [45] interpreted that *"experience is something*

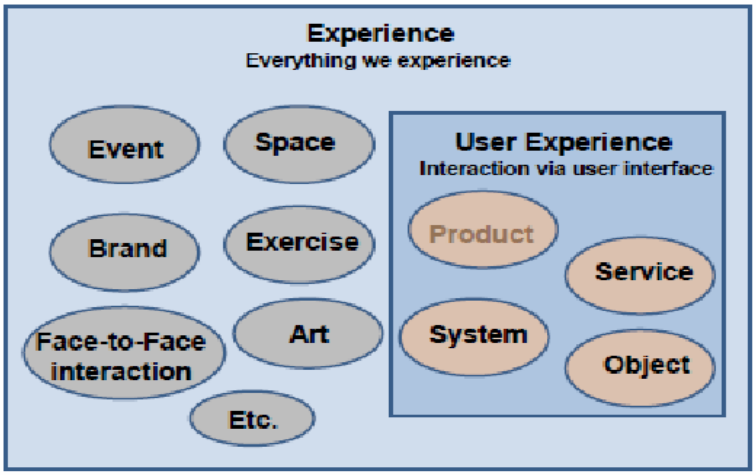

Figure 3.2: UX in relation to other experiences [45]

personal,something within a person and only individuals can have feelings and experiences". It claims that this understanding is in-line with the definition of UX given by recent ISO 9241-210 standard [5]. ISO 9241-210 defines UX as *"a person's perceptions and responses that result from the use or anticipated use of a product, system or service.* However, I disagree with the recommendation[45] and the definition given by ISO 9241-210 standard. There are two strong reasons to support this disagreement - First, both of these ignores temporal nature of UX (see Section 3.3.3) and focus on immediate use of a product i.e. perceptions and responses. I consider temporal nature of UX as far more complex then the anticipated use. Second, both these are influenced by the views of UX practitioners because ISO standards are made by a board of internationally renowned researchers and practitioners in the area of question and Law et al. [45] survey was also filled by those researchers and practitioners.

I interpret UX as a combination of social and individual factors. UX is influenced before, during and after interacting with a product. As group can experience together, similarly an individual can do it from its own eternal

conscious and unconscious thinking. My viewpoint is in-line with the Feature triangle (see Section 4.2) that states UX is affected by social interactions and design features of any product. Social context affects UX just like other contexts like task performance, technology and product design. UX is more than just interaction with products. It is not limited to artifacts because when any user interacts with a service or product then it also interact with the organization that has created that particular service or product.

3.3 User Experience Frameworks

UX takes an extended perspective on the users' interaction with the product. It goes beyond the traditional usability where satisfactory, pleasant and efficient interaction with the product is more important than only product usability. It further extends this interaction experience to an emotional relationship between the user and the product. There are several frameworks and theories that have been purposed to define this concept. In this chapter, I have discussed only three frameworks which are in-line with the scope of this thesis. These frameworks help in defining the characteristics and dimensions of the UX.

3.3.1 An interaction centered framework for User experience

Forlizzi and Ford [21] emphasized the need for designing UX for which product designer should discover methods of designing experience. Forlizzi and Ford [21] answered the question *"how interaction design and product design achieve specific UX goals"* by an initial framework for experience (see Figure 3.3). It acts as a guideline for product designers so that they may think about the kind of experience they are designing for their users. The framework present four dimensions of experience - *"Subconsciousness"* meaning *"automatic and fluent experiences that happen in our daily routine"* for example series of routine activities that we perform using different products that *"do not compete with our attention and thinking"*. Furthermore, we learn how to use any product once and then use them without thinking or any cognitive load. *"Cognition"* refers to *"those experiences that involves "users' special attention, cognition effort or problem solving skills"* for example experiences which probe oneself to *"what we are doing"* such as interaction with new, unfamiliar and confusing products. *"Narrative"* means those experiences that are defined and formalized in the users' mind. A product has certain features which forces us to start thinking about *"what we are*

doing and experiencing". Its *"functionality and affordance offers a narrative of use"*. Finally, *"Storytelling"* is an act when any user traverse from one important experience to another and create a personal story from those experiences. Users' interaction with a subset of product's features is influenced by context, past experiences and present state of mind. These finally result in the creation of a unique and subjective story. [21]

The shift between different components of this framework helps in understanding various product and user interactions. We experience several sub-conscious experiences daily such as morning walk, making morning coffee or driving car. All these experiences have become automatic as we practice them daily. The experiences shift from cognitive to sub-conscious when we get used to any product or activity. This shift reveals that a product is usable and learnt with less effort. On the contrary when any experience shift from sub-conscious to cognitive then it means user has encountered some unexpected events during its interaction with the product. It also shows that design or the product does not match with the users' mental state. However, this shift can also be interpreted as user is creating new knowledge and that learning is taking place. [21]

The shift from narrative to cognitive experience happens when we are forced to challenge our thinking during a product or service interaction that has made deep into our beliefs, attitudes and perceptions. For example, after watching a commercial for doing social work in Africa on television changes our attitude and opinions. Sub-conscious experience changes to storytelling when we communicate interpret and add different meanings to it. For example, we talk about our experience in a conference get together, covering different aspects of our experience from meeting colleagues to the discussion on important keynotes of that moment. [21]

Similarly, an experience can move from narrative to storytelling when an experience become personalized on communicating it to others for example, after interacting with a futuristic technology that makes human life easier then we often communicate this experience while sitting in a group of people. This shift from sub-conscious to narrative and finally to storytelling shows that human beings have the need to share experience as story. These facts are important for any designer in order to understand users. [21]

Forlizzi and Ford [21] classifies experience into three categories as *"experience"*, *"an experience"* and *"experience as story"*. Later Forlizzi and Battarbee [20] extended this classification and changed the *"experience as story"* with a new concept called *"Co-experience"*. A framework for UX and product user experience is created based on the three modified dimensions (see Figure 3.4). Forlizzi and Battarbee [20] presented a framework for designing experience in the interactive products based on the different existing ap-

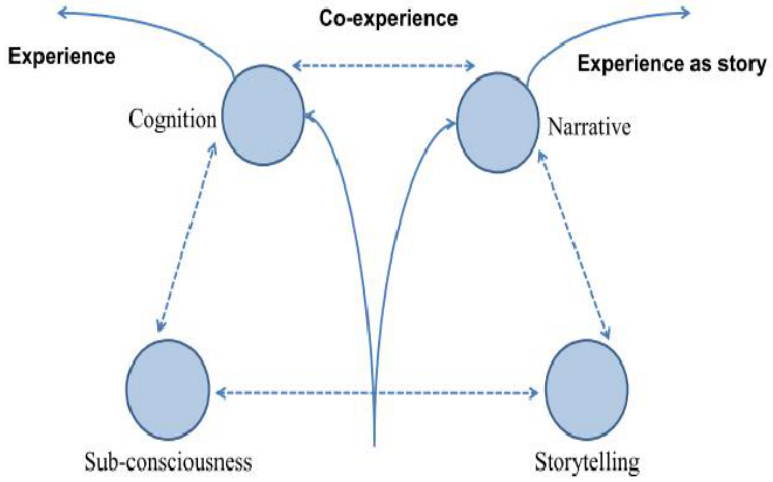

Figure 3.3: An initial framework of experience [21]

proaches to experience in other disciplines (see Figure 3.4). It can be applied by multidisciplinary team for understanding and generating different kind of experiences, any new product design might offer.

Users act in a particular context of use that is influenced by social and cultural issues. For example, people around the globe watch TV programs on their TV but programs vary from one country to another. Moreover while watching TV program we are either alone or with one or more people. The language, volume and type of program are adjusted based on the context of use. When any user interacts with a product then his/her experience is influenced by their past experiences, emotions and cognitive skills. Furthermore, product's features and its utility also have impact on the users' experience [21].

3.3.2 Factors affecting User experience

Hassenzahl [25] purposed two distinct product characteristics as pragmatic and hedonic attributes. The pragmatic attributes are associated with the behavioral goals which require utility and usability. Hedonic characteristics are associated with the users' self such as pleasure and emotions that have influence over the individuals' psychological existence. Furthermore, Hassenzahl [25] described two distinct evaluative judgments for the quality of any interactive product as beauty and goodness. It was found that goodness is affected by the pragmatic aspects like usefulness and usability while beauty is considered as a social aspect affected largely by the identification of the product. By identification we mean product's ability to express identity of its

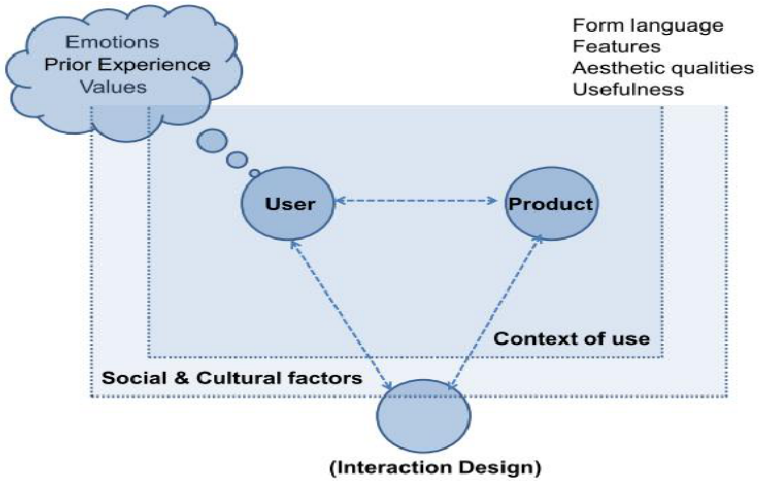

Figure 3.4: User experience and product user interaction [21]

owner. The goodness of the product changes by experience and utility of the product gains importance after the first interaction. Moreover, beauty factor was found not affected by initial usage experience and stimulation (product's ability to address the human need of stimulation) did not have major effect on the evaluative judgments.

Hassenzahl [24] gave a model for UX having two perspectives, one for designer (see Figure 3.5) and other for users (see Figure 3.6). A product has certain features also referred as product character like content, functionality, ease of user or pleasure and satisfaction. A designer chooses product features (content, presentational style, functionality, interactional style) in order to convey the intended product character. Product character can be summarized as novel, interesting, predictable, useful while character's function is to reduce cognitive load and trigger strategies for handing the product. In contrast to the designer's view, users' view on product character is far more personal, change over time, situation dependent and state of mind. The episode of user interaction with any product can be described as - when any user comes in contact with a product then a process is initiated. First, the user perceives product features and based on this, user *"constructs a personal product character"* which is referred as *"apparent product character"*. It consists of both pragmatic and hedonic aspects. After this, user makes *"evaluation judgments also called consequences"* based on the product's character such as *"product's appeal, emotional consequences and behavior consequences"*. [24] For example, using fast wireless Internet on big mobile screen can be pleasant, satisfying and efficient but if the Internet access speed is bad then this experience can easily become frustrating.

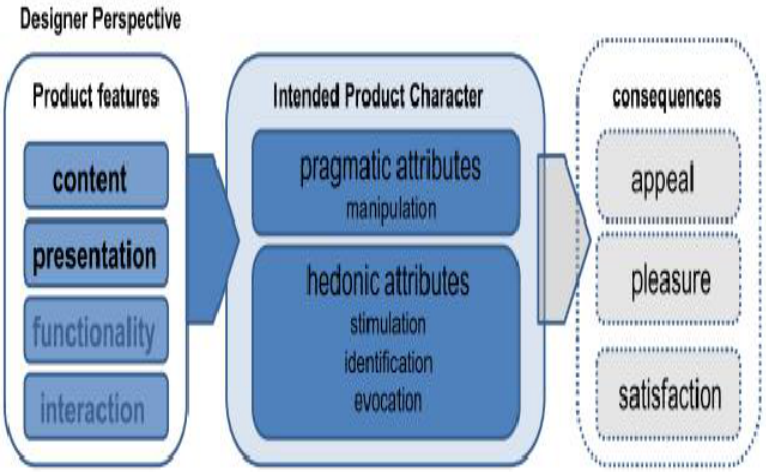

Figure 3.5: Hassenzahl model of UX - Designer view [24]

Hassenzahl [24] described usage modes as important in evaluating UX because context of use affects UX. Usage modes are situations when a product is in use and it can be either goal oriented or action focused. In former mode, a user tries to achieve the goal with efficiency for example an ambitious student who want to complete his studies on time but with good grades. The latter case is action oriented where achieving final goal is not relevant for the user for example, sharing status messages on social networks is action mode activity and user spends hours on it.

Jordan [34] stated that qualities that contribute to a positive experience exist in a fixed hierarchy (see Figure 3.7(a)). A product has to provide useful and usable functionality before the hedonic aspects such as stimulation, beauty and pleasure can take effect. However Karapanos et al. [37] disagree with this model and stated that different qualities vary with different contextual factors (see Figure 3.7(b)). Different individuals appreciate different qualities of an interactive product while some prefer simplicity and austerity; others prefer playful and stimulating products. Furthermore, the same product can be used in different situations depending upon the importance we attach to different qualities likewise, mobile phone is used for sending text and making calls but same mobile phone is used for listening songs in a leisure time. Overall the factors like individual and type of product will influence the qualities in satisfying experience with any product. [37] Hassenzahl [24] describes pragmatic and hedonic characteristics as independent but if taken together then they form a product character. *"Users' perception of hedonic and pragmatic parameters can be either weak or strong so total of four combinations can happen"*. A product can appear pragmatic or hedonic to different

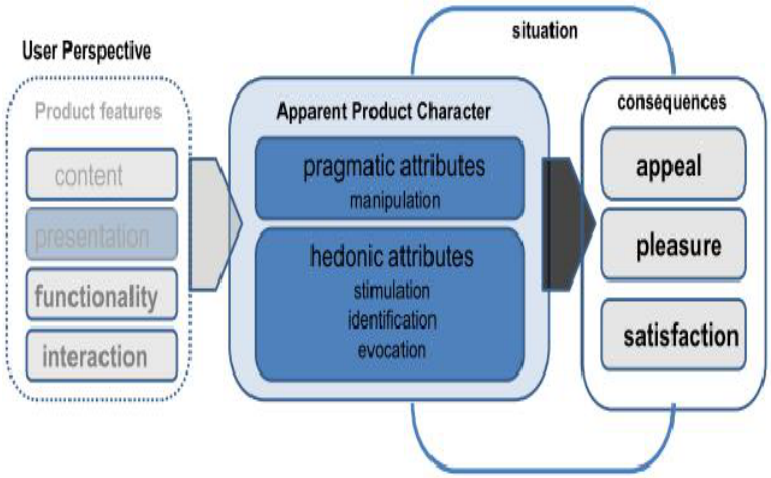

Figure 3.6: Hassenzahl model of UX - User view [24]

people for example for those users who are brand conscious, a product is hedonic if it communicates their identity to their social settings while for users who prefer simplicity and efficient, for them a product may be pragmatic. Hassenzahl [24] gave a 2x2 matrix to discuss the varying product characters from the combination of hedonic and pragmatic attributes (see Figure 3.8). The combination of weak hedonic and weak pragmatic attribute means unwanted product as it neither satisfying pragmatic nor hedonic needs of the users. A combination of strong hedonic and strong pragmatic attributes is always wanted in the desired product. Furthermore, it defines SELF as product character when hedonic attributes are strong and pragmatic attributes are weak and similarly ACT product character when vice-versa happens. The ACT product character is linked to the users' behavior goals that are either external or internally generated by an individual. Depending upon these goals, importance of the ACT varies. For example, if a user has bought a new pragmatic apple iPod for listening songs while commuting to and from office. Unexpectedly, if someone offers the same user a new apple iPad for free then suddenly, the new iPad start looking more appealing than the iPod. The reason for this change in the behavior goal that user meant to fulfill with the iPod has ceased to exit. In contrast to ACT, the SELF product character is linked to users' self, example their ideas, memories and relationships. [25]

3.3.3 Temporal Nature of User Experience

Products are responsible for evoking our memories, providing personal growth, and establish our self-identity in social settings [51]. Temporary nature of UX

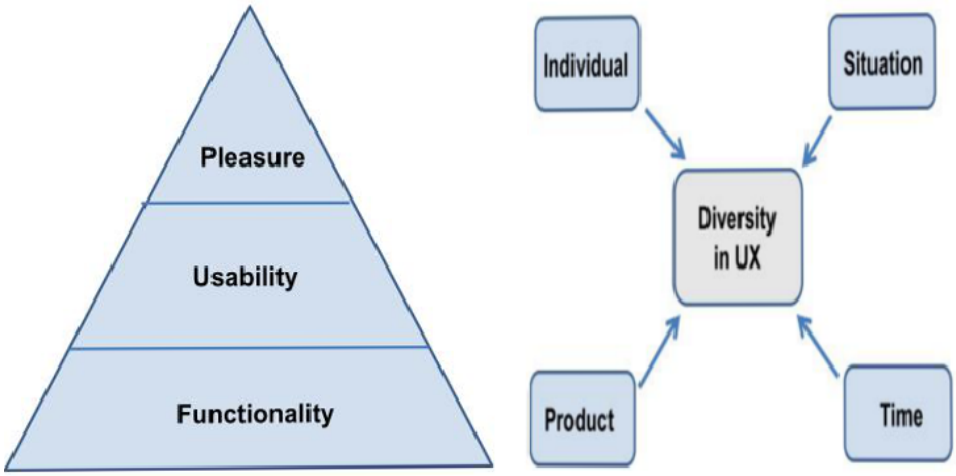

Figure 3.7: a) Jordan fixed hierarchy of needs [34] (b) Four sources of diversity in UX [37]

is less studied subject. Temporarily of UX means UX continuously develop over time. The excitement of interacting with a brand new product fades away after familiarity with the product increases. This shows that perceived quality of any product changes over time. Learnability and uniqueness of the product are important in the beginning while usefulness and self identity in the social settings might decide the prolonged use of any product. [37] Kankainen [35] gave a conceptual model for UX with emphasize on its temporal nature (see Figure 3.9). It states that UX is the result of motivated action in a certain context. The context can be places, people and things around the user while motivated actions means the driving force required by user to act with the product. Motivation can also be interpreted as user needs which arises from physiological states of tension such as pleasure, hunger or thirst, and psychosocial states of tension like need for self-esteem. When a need reaches a sufficient level of intensity in a particular context then it becomes motive and its satisfaction eases the felt tension. Users also possess action level needs beside the motivational needs where the former answer *"how the user is doing"* and later answers *"why a user do this and what a user do"*. Kankainen [35] emphasized that user's previous experiences and expectations influence the current experience. Similarly, the present experience leads to more experience and modified expectations. For example, suppose Alex always eats at a particular restaurant that serves good quality and tasty food at cheap prices. Due to this, Alex has built high expectations from his past experiences. One day Alex's friend Peter invited him for having lunch together at some different restaurant. The food served was neither

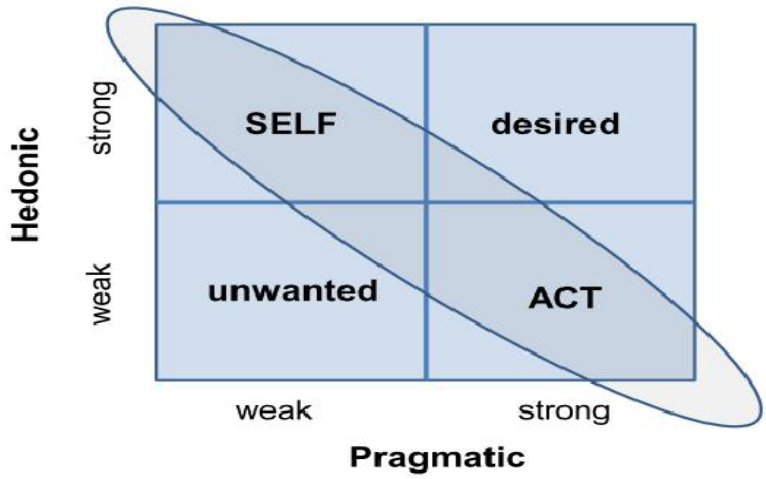

Figure 3.8: Four types of product character [24]

tasty nor it was of good quality. This has turned Alex experience negative because food was not outstanding contrary to his expectations. Now next time when Alex will go out for lunch to the same restaurant then he will keep low expectations from the served food. This can also be interpreted as, Alex will never visit that restaurant again due to last time disappointment with the food served. Karapanos et al. [37] stated that it is important to

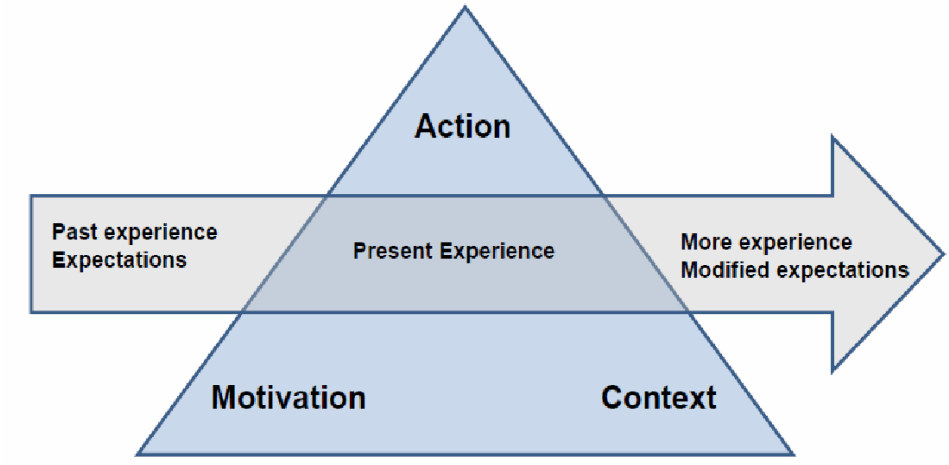

Figure 3.9: Conceptual model for User experience [35]

understand those factors on which users make overall evaluative judgments on the quality of interactive products. The prolonged use of a product is motivated by different qualities rather than the ones that provide positive

initial experience. Furthermore, early experiences are mostly influenced by the hedonic aspects of product use while prolonged experiences are influenced by aspects reflecting how the product becomes meaningful in one's life. UX of any product consists of three phase namely initial orientation, incorporation and identification. In each of these phases, different product qualities are appreciated. Furthermore, there are three main forces such as increasing familiarity, dependency and emotional attachment that are responsible for shifting users' experience. [37] Karapanos et al. [37] stated that nowadays, product need not only be useful and usable but also stimulating, pleasurable and beautiful. It shows that users value both pragmatic and hedonic aspects of any product design.

3.4 Evaluating User Experience

When products are designed and created then it is likely that most of the decisions are based on the personal evaluation, skill-set and judgments of the designer [58]. Product designers consider designing UX not only challenging but difficult too. They often need to keep track of different aspects such as usability, contextual factors, hedonic and emotional aspects. To fulfill this aspiration, subjective, objective and emotional UX evaluation tools or metrics are available. UX evaluation refers to well defined and quantifiable tools or metrics that are employed to determine the users' expectations before using the product and users' perception after interacting with the product [58]. Measuring UX is one of the research question (see Section 1.3) behind this thesis.

There is a need to have some means for evaluating UX as this will potentially help designers to consider UX factors and base their design over it. Measuring UX is not only challenging but risky too if correct method, study setting and test participants are not chosen.

I used three different UX evaluation methods for evaluating UX of MMR prototypes and proofs of concepts created through UCD. UX evaluation can potentially give reflection on the created concepts like how well certain UX aspects have been considered and which UX aspects have been ignored or not given proper attention. I used the adapted versions of three UX evaluation methods i.e SUXES [64], AttrakDiff [25] and Emocard [63] (see Section 3.4.1-3.4.3) and empirically tested in the later part of the thesis (see Chapte 6).

There exists several UX evaluation methods[1] so it was hard for me to choose those methods that can return best results. I selected above three

[1]http://www.allaboutux.org/ Last visited on 15 March, 2011, 8.51 AM

evaluation methods keeping in mind the goals behind this chapter i.e. to evaluate UX of MMR prototypes and proofs of concepts. All the three methods complement each other nicely, i.e. triangulation in data gathering. Emocard helps in evaluating the non verbal emotional response, SUXES enables me to evaluate the subjective UX and AttrakDiff helps in evaluating objective UX of MMR prototypes and concept. A combination of SUXES, AttrakDiff and Emocard made it possible for me to evaluate subjective, objective and emotional UX of MMR technology. This selection is also influenced by the research questions (see Section 1.3) behind this thesis.

3.4.1 SUXES

SUXES is a subjective UX evaluation method that is primarily used to evaluate UX efficiently in speech-based and multimodal systems [64]. SUXES helps in capturing subjective metrics that includes both user expectations and user experiences through empirical experiments with users [64]. There are two main supporting reasons for choosing SUXES in MMR namely

1. SUXES methodology complies with research questions behind this thesis (see Section 1.3) i.e. finding user expectations and evaluating UX.

2. SUXES helps in evaluating the temporal nature of the UX (see Section 3.3.3) as SUXES not only collects pre-use expectations and post use perceptions but also helps in analyzing the state of the product and its interaction methods, and compare results [64].

SUXES is a suitable method for iterative developing and prototyping as it provides contextual insights that can boost further development efforts. SUXES indicates *"what are the strong features"* and *"what areas require further improvement in any product or service"* [64]. However, in this thesis I employed SUXES methodology only for evaluating the UX but the future work can include introducing SUXES into the UCD life-cycle of MMR for example.

SUXES is adapted from SERVQUAL [55], a method for evaluating service quality in the domain of marketing. SUXES method does not give a strict or well defined structure for the process implementation. However it states important guidelines that are helpful in implementing SUXES depending upon the nature of the product to be evaluation. SUXES metrics is divided into four phases having total of eight steps (see Figure 3.10). The original diagram [64] describing different phases of SUXES is not clear so I modified it and added more clarity into its description. The eight steps are performed at different times and overall SUXES process is either partially automated using

web wizard or conducted manually by using printed papers for instructions and experiment. The four different phases of SUXES are described through eight steps as follows (see Figure 3.10)-

Step1: Introduction to the evaluation

Step2: Background questionnaire

Step3: Time reservation for testing prototype

Step4: Introduction to the prototype

Step5: Expectation questionnaire

Step6: Test with the prototype

Step7: Experience questionnaire

Step8: Feedback questionnaire

Phase First: Background information First phase consists of three steps namely first, second and third step performed in a sequential order. This can be performed either remotely or in the formal settings such as usability laboratory [64]. In first step, participants are introduced with aim of the evaluation and best practices of usability evaluation. In second step, participants are required to fill a background questionnaire covering questions related to age, sex and previous usage history related to the product or service in question. Third step is optional where participant makes a reservation for the actual test. However, if the actual test is performed at the same time then this step is followed after the step 5.

Phase Second: User Expectations Second phase consists of fourth and fifth step. In the fourth step, participants are introduced with the product or service in question and it must be observed that actual usage instructions are not revealed at any step of the study. Different tools can be used such as video based instructions, storyboard and textual information. It is important to give a realistic view of the product without giving too much detail. This also helps in capturing the expectations precisely. Fifth step deals with collecting user expectations through a questionnaire. Participants fill in the questionnaire based on the training provided to them in the step four.

SUXES has defined a collection of nine statements for each item or application to be evaluated. These statements related to speed, pleasantness, clearness, error free use, robustness, learning curve, naturalness, usefulness,

and future use. For example a statement like *"'mixed reality application is efficient in use"* is meant to judge the efficiency of MR application.

The questionnaire contains statements that are answered in the scale of one to seven. Participant chooses two values, an acceptable level and a desired level for every statement. By acceptable, I refer to lowest level of quality that is adequate for the participant and desired level is the highest level of quality at which participant considers no point of going further.

Phase Third: Experiment and User Experience Phase three contains two steps namely sixth and seventh step. In the sixth step, experiment is conducted as test participant makes use of the actual product to execute a list of tasks. In case of any difficult, participant can directly ask to test moderator. This phase can be conducted remotely and also supports mobile experiments. The seventh step deals with gathering UX based on the actual use of the product. Participants fill in an experience questionnaire and it contains same statements that are used in expectation questionnaire. The difference here is, participant gives only one value for perceived experience in each statement.

Phase Fourth: Feedback In final phase, the participants fills opinion questionnaire in eighth step. There is no standard set of questionnaire as every experiment differs from other due to different product concept, test situation and different possibility for getting opinion and comments. So the questionnaire is individual to every experiment. Furthermore, this questionnaire can also be replaced with an interview.

3.4.2 Emocard

Recently, research on evaluating emotions has received attention in different HCI conferences. Humans are driven by emotions and it is also often said that emotions is a fundamental component of human being. Emotions can influence users' satisfaction and acceptance towards any product or service. Erevelles [17] stated that emotions can even influence the purchase intention and is an important determinant of consumption behavior. So far most of the research on emotions is focused on emotion metrics but on theoretical level [12]. Only few case studies exist on examining emotions in context to evaluating UX.

Before actually discussing emotion evaluation I need to answer first, what are emotions? In practice, there exist many definitions of emotion so it is both hard and challenging to find one precise definition that is also scientifically

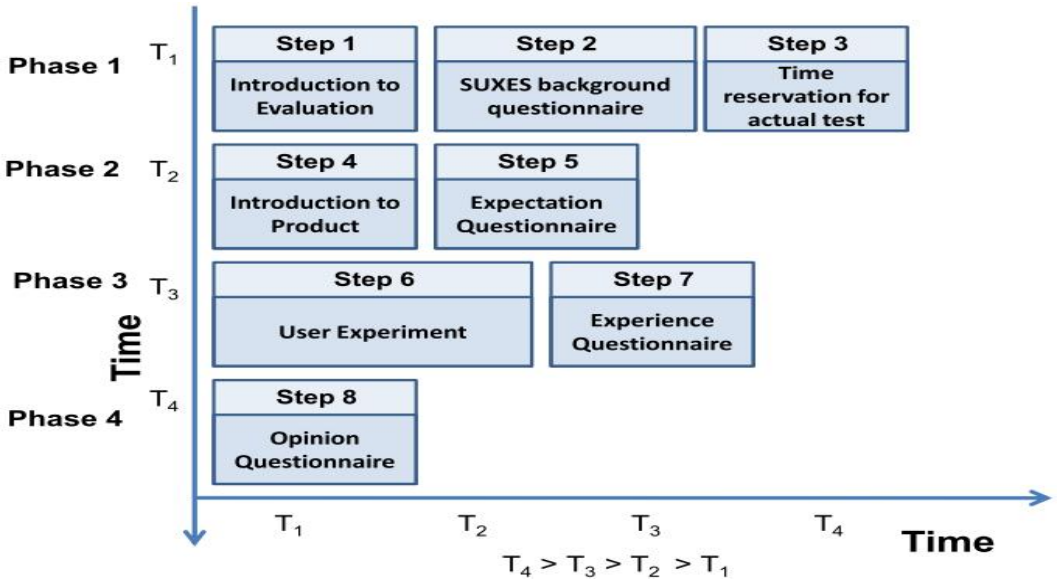

Figure 3.10: Modified SUXES Evaluation Metrics [64]

correct. However, there exists an agreement on *"what actually constitutes human emotions"* [12]. First, emotion is a psychological reaction to events such as our needs, goals and concerns. Second, emotion is a combination of physiological, affective, behavioral and cognitive components.

Due to inherent relationship between emotions and product's acceptability, they are considered key in determining UX. Andrew and Agarwal [6] claimed that *"emotion assessment helps in better understanding the UX.* However, evaluating emotions is not only complex but also challenging as users often face trouble in explaining as how they feel. Moreover, users cannot even differentiate between different emotions due to the instantaneous nature of emotions [15]

There are several emotion evaluation tools that help to capture and interpret emotions. These tools are broadly classified as verbal and non verbal evaluation tools. Verbal emotion measures include self reports where test participants use a scale to record their emotions. Non-verbal evaluation uses different visual representations of the emotions from which the test participants choose how they feel. [6]

In this thesis, I used only non verbal tool for emotional reponse evaluation. Non verbal tools involves human like deceptions that have been validated cross-culturally so they are reliable in their interpretation. Non-verbal tools attract a wider audience compared to verbal techniques because they capture conscious state of human mind unlike verbal measures [6]. Evaluat-

ing emotions can enable product designer in better understanding the UX. In order to attain this goal, I used Emocard [15] which is a well known non verbal evaluation tool. Emocard is used in evaluating users' emotional response against MMR prototype and proofs of concept created in Chapter 5.

There are numerous emotional response evaluation tools available in existing literature but I did not found single emotional evaluation technique that alone is reliable for the assessment of emotional response. I was aiming at finding a quick and easy method that can help in evaluating the users' emotional response against MMR prototype and proof of concept in a cost effective way. Andrew and Agarwal [6] stated that most of existing emotional response evaluation tools are very much experimental and of unknown validity. Due to these reasons, I first decided to use a combined verbal and nonverbal emotional evaluation as done by Andrew and Agarwal [6] but later I decided to perform emotional evaluation by using Emocard only. There are two main supporting reasons for my decision namely - first, verbal emotional response techniques like PAD differential scale [48] has several overlapping statements to AttrakDiff questionnaire so making use of PAD or similar verbal emotional scale will result in a double effort from test participants' end. Second, my study already contains variety of UX evaluation methods such as SUXES, AttrakDiff and Emocard so having one more additional metric will result in a heavy and lengthy study that can make test participants' experience dull and boring.

Emocard is widely used and empirically supported technique but its validity in evaluating UX of mobile applications such as MMR is unknown. Emocard helps in refining the experimental technique to boost my emotional response evaluation methodology.

Emocard consists of 16 different cartoons like faces (half male and half female faces)(see Figure 3.11). These faces represent different emotion and each face shows combination of two emotion dimensions such as pleasure and arousal. Now based on these dimensions Emocard is divided into four quadrants - calm-pleasant, clam-unpleasant, excited-pleasant and excited-unpleasant. In Emocard study, if the user reaction is more pleasant and higher in the arousal then it is considered desirable. Moreover, if the users' responses are more towards the calm-pleasant and excited-pleasant then it is understood as positive results. [6]

Emocard faces can be confusing to some users and it is also possible that users cannot interpret the meaning of different faces if used in users study. This was found with two pilot tests performed by me during UX evaluation (see Chapter 6). In order to bridge this challenge faced by Emocard, I took three preventive measures namely 1) I added description and explanation for each pair of faces based on Tähti et al. [63]. 2) I gave training to participants

on how to interpret Emocard and how to give responses based on different combination of faces. 3) All test participants are asked to first perform two dummy tasks using Emocard before performing the actual test. For example, *"what is your emotional response when I ask about your workplace?"* and *"What is your emotional response When I ask about your current living place?"*

Emocard	Explanations
	**Excited Neutral** Quite ok, Useful but slow, No idea what I am doing
	**Excited Pleasant** Positive, Nice to test and Funny
	**Average Pleasant** Nice to test, Easy to use. Nice experience
	**Clam Pleasant** Easy even for me, Quite good, Usage as expected
	**Clam Neutral** Getting tired, Complex and problematic, Neutral
	**Clam Unpleasant** Difficult to use, unfinished demo, less than expected
	**Average Unpleasant** Not working properly, Difficult to use, Don't know how to use
	**Excited Unpleasant** Causing anxiety, not working as expected, jammed

Figure 3.11: Overview of Emocard having added explanations [63]

I modified the simple emocard method used in the earlier studies [6]. The method is not changed as such but further explanations and interview component is added to gather qualitative feedback of the participants. This kind of modification is essential for getting rich user data during UX evaluation. Emocard alone is not suffice and participants' reponses can be hard to understand if qualitative explanations are not gathered. This was found during the pilot test. The Emocard study can be performed in three phases if only one prototype/concept is available for UX evaluation. However if the number of prototype and concept is two then Emocard study can be completed in six phases (see Figure 3.12). In the first phase, participant is introduced with the study setup and given training on using Emocard. Participant is intro-

duced with concept/prototype in phase second for which emotional response needs to be evaluated. In third phase, participant is instructed to answer Emocard based on their experience with the prototype/concept in phase second. Later, participant is interviewed for getting qualitative opinion on the shown concept. This process is repeated for any number of prototypes and concepts.

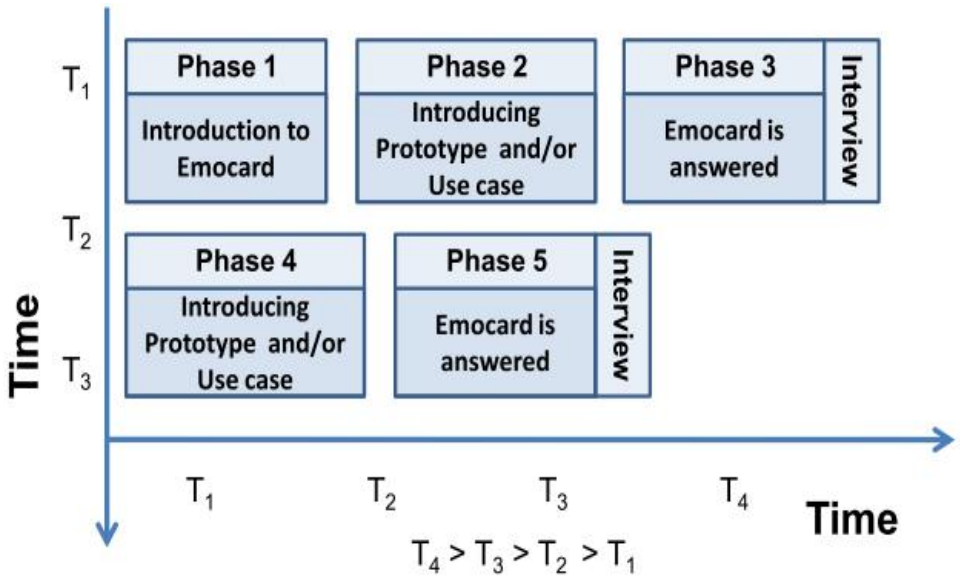

Figure 3.12: Overview of Emocard study process

3.4.3 AttrakDiff

Hassenzahl [25] purposed that every product has two distinct characteristics namely pragmatic and hedonic attributes (see Section 3.3.2). Furthermore, both pragmatic and hedonic qualities are essential components of UX. Hassenzahl et al. [27] defined UX evaluation metric called AttrakDiff questionnaire for evaluating the pragmatic and hedonic qualities of UX for any product or service. AttrakDiff questionnaire is documented in German [27] and I possess zero German language skills. It was challenging for me to understand this questionnaire and conduct studies using AttrakDiff in English. To solve this challenge, I registered at AttrakDiff[2] website and downloaded the web version of the AttrakDiff questionnaire in English. AttrakDiff questionnaire contains 28 different attributes and I categorized them into three

[2]http://www.attrakdiff.de/en/Home/ Last visited 11.00 am, 28 May, 2011

main groups namely - perceived hedonic quality identification (HQI), perceived hedonic quality stimulation (HQS) and perceived pragmatic quality (PQ) (see Figure 3.13) [25]. All these attributes are evaluated using bipolar semantic differential 7 scale methods [25].

A study using AttrakDiff questionnaire can be performed in four phases (see

AttrakDiff	Attributes	
Hedonic Quality Identification (HQI)	Stylish Predictable Cheap Alienating Un-presentable Rejecting Unimaginative Good Brings me closer to people	Tacky Unpredictable Premium Integrating Presentable Inviting Creative Bad Separates me from people
Hedonic Quality Stimulation (HQS)	Confusing Repelling Bold Innovative Dull Undemanding Motivating Novel Unruly	Clearly Structured Appealing Cautious Conservative Captivating Challenging Discouraging Ordinary Manageable
Pragmatic Quality (PQ)	Human Isolating Pleasant Inventive Simple Professional Ugly Practical Likeable Cumbersome	Technical Connective Unpleasant Conventional Complicated Unprofessional Attractive Impractical Disagreeable Straightforward

Figure 3.13: Overview of Bipolar attributes of AttrakDiff [25]

Figure 3.14). In the first phase, participant is introduced with the study setup and given training on using AttrakDiff and its 28 attribute scale. Participant is briefly introduced with concept/ technology in phase second. In third phase, participant is instructed to answer AttrakDiff based on the introduction to the technology/concept in phase second. In fourth phase, participant is introduced with prototypes or proofs of concepts for testing. In fifth and final phase, AttrakDiff questionnaire is again filled by the participant based on their experience with the tested prototypes and proofs of concepts.

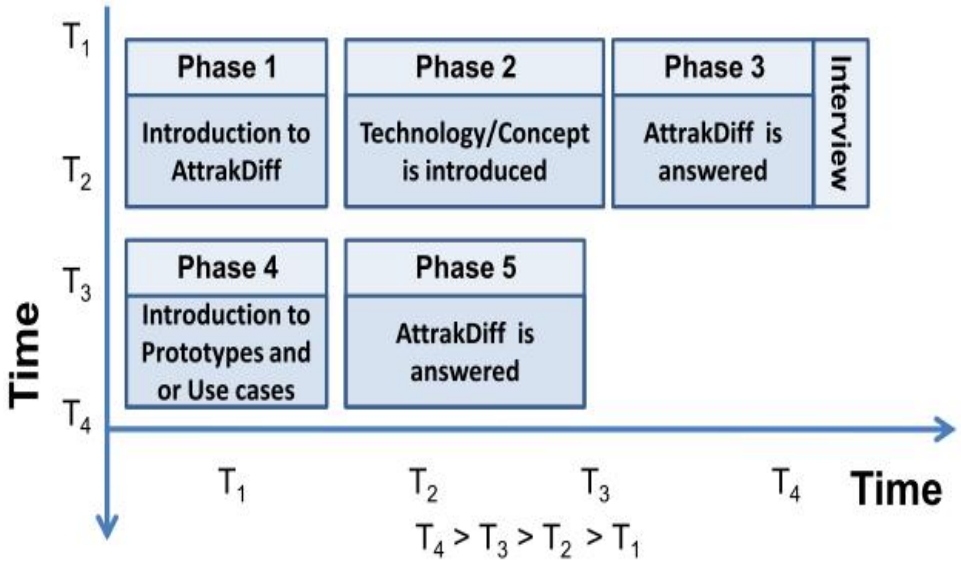

Figure 3.14: Overview of AttrakDiff study process

3.5 Summary

In this chapter, the concept of UX is introduced, challenges in defining UX are discussed and various definitions pertaining to UX are presented. Different theoretical frameworks on UX are discussed in order to understand the different aspects of UX. When a product is to be designed then it is important to consider different context of its use because a user can use the product in different forms like goal or action mode. The different aspects of UX need to be considered in order to understand UX of different interaction techniques. Like interaction with the product can bring social, physical, psychological, ideological pleasures and satisfactions to its user when used. The past-experiences and expectations can have strong influence on UX. Furthermore, experience changes over time. Both aesthetic and pragmatic characteristics of the product influence the UX.

Evaluating UX is equally important as designing UX. I have presented three UX evaluation methods that covers subjective, objective and emotional UX evaluation. UX evaluation helps designers and product engineers in better understanding the current level of their design. The evaluation part of UX is presented in Chapter 6.

Till date, the research on MMR or AR in general is concentrated mostly on the technological aspects such as developing enabling devices, algorithms for location-aware events, efficient displays and so on. User research part

in the application development is mostly performed after the application is developed. Moreover, the reason for performing user studies was to evaluate the product and improve usability related aspects.

Despite of having a larger active community of researchers working on AR research from a number of years, the role of UX in this field has been completely ignored. Currently, AR research lacks understanding of the needs and expectations of the users from AR based services. There is a need to understand the importance of UX and other user centered methodologies in developing AR solutions especially the hedonic and emotional aspects of UX.

UX is a widely studied subject but lacks a precise definition. UX should be studied and applied depending on the context. In this thesis, our definition of UX is modified form of the Law et al. [45] statement. Thus, *"UX occurs when a user interacts with a product individually or socially via an interface"*.

Chapter 4

Reviewing AR Literature and Applications

In this chapter, I present both the theoretical background in form of review of existing AR mobile applications and empirical analysis in form of a feature triangle and comparison table based on the discussion of described AR applications. I used heuristics (see Section 2.5.1.3), for reviewing the AR and MMR applications. The presented AR applications have similar design perspectives and characteristics compared to MMR. This background review helps in investigating this research theme from a wider point of view. The chapter concludes with a feature triangle (see Section 4.2) a tool for comparative analysis of different AR applications in a three-dimensional feature space and a comparison table (see Section 4.3) that enlist summary of the requirements for a future MMR application.

4.1 Review of existing AR Applications

In very beginning of the thesis work, I thought of reviewing existing applications in AR/MMR domain as this can potentially guide me in designing my own MMR application. However, when I searched the digital libraries of ACM[1] and IEEE[2] I found that large number of papers with AR/MR applications. My overall aim was to describe different features available in current AR applications as these features can potentially help me in focus group discussions where I can test my initial ideas based on the functionalities of the existing systems. Later I decided a criteria for selection, my list should include both AR and MMR applications from gaming, tracking, reminder

[1] http://portal.acm.org/
[2] http://ieeexplore.ieee.org/

system, education and tourism.

A total of 11 different applications and concepts from AR-MMR family were reviewed. It includes both type of applications i.e. created by research community for evaluating a particular concept and those deployed by industry with commercial interests. The review criteria and process can be explained as follows- First, list containing information on 25 different MMR/AR applications to be reviewed and their respective sources containing documentation was prepared. Second, for all 25 different applications, information on its technical architecture, functionalities, merits, demerits, new features, problems and opportunities were prepared. Third, all applications were arranged under the broad categories like *"Travel"*, *"Gaming"*, *"Education"*, *"Tracking"* and *"Mobile device"*. This was essential in order to perform selection of applications and reject those that are not important. I ignored 14 applications from the original list of 25 as some were similar and others do not have any new element in terms of application design and technology concept. By new elements of application design, I refer to *"What is new in the application"* apart from having multiplayer, location tracking, geo tagging, location awareness, gaming and so on. Broadly, I was looking for new ways of performing orchestration of MR view and new concepts on supporting MR technology in daily routine.

This has helped in finding design themes, functionalities, features and requirements for supporting MMR experiences. This list of experiences and functionalities are used in focus group interviews as a part of UCD methodology (see Chapter 5). The applications presented are not the only ones that exist in this rapidly growing domain. My list contains only a handful of importantÂ applications although many such implementations and publications exits dealing with this matter.

4.1.1 Urban Tapestries

Urban Tapestries [43] is software platform for creating social and mobile experiences. It aims to develop a demonstrable prototype having open access to creating and publishing location specific content. It enables its users to share content based on their experiences for example creating and publishing media annotations such as text, audio and pictures on the map of the city. The system consists of GPS enabled mobile phone and wireless connectivity. A central repository is responsible for serving maps to the users' mobile device. The framework provides alerts to the user when it reaches the specific location similar to Location based reminder (LBR) systems. But user has to specify content and associated location as in other LBR systems.

Urban Tapestries has one interesting feature that it aims to be dynami-

cally interactive mobile application (see Figure 4.1). It enables its users to provide content based on their experiences. They can freely annotate the paths and add different media content to it. I consider this feature important for our application too, so I will further investigate such functionalities during the user research.

One major contribution of Urban Tapestries is that it provides players with tools to annotate maps in order to enhance the community engagement.

Figure 4.1: (a) Urban Tapestries on mobile [43] (b) Urban Tapestries map view [43]

4.1.2 Geo Tracing

GeoTracing [1] is a software framework for developing geo-based multimedia applications. It is based on the idea of serving location based content to mobile users for example when a user reaches an annotated location then existing annotation information attached to that location is displayed on the mobile screen. The annotations can be textual, audio, video and pictorial information. There are many applications developed using GeoTracing framework such as GeoSaling, Traceland, GeoBiking and GeoSkating. GeoTracing framework consist of three modules namely MobiTracer, WebEditor and WebViewer (see Figure 4.2). The MobiTracer module runs on a mobile phone that enables its users to upload position data, track information and track media annotations (such as ratings in the form of images, text and video) to the central server of the framework. Through the WebEditor which is an interface from where users can manage their personal tracks. It

allows the uploading of routes and annotations gathered from offline GPS receivers. WebViewer is a web interface that displays read only information such as live tracking of the mobile users and displaying maps with routes and annotations.

Main problem with the GeoTracing is that it is heavenly dependent upon the GPS for tracking so possible GPS errors and fluctuations in wireless connectivity can easily affect the experience of its users. GeoTracing has many similarities compared to the Urban Tapestries forexample, it also enables its users to upload pictures and annotate textual information about a given route. However both are different interms of their technological environment.

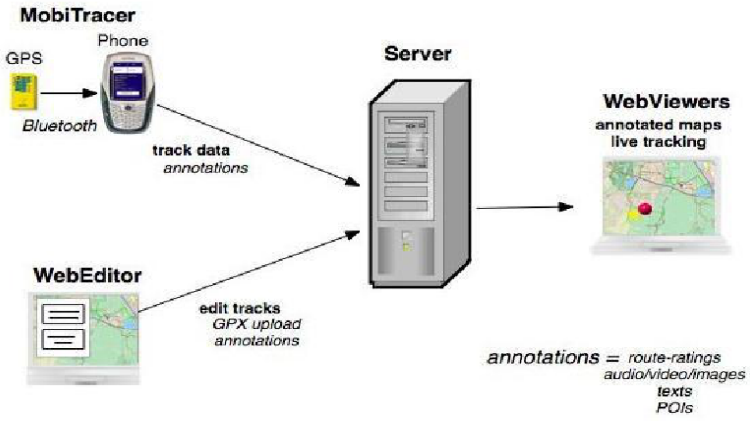

Figure 4.2: Overview of GeoTracing Framework [1]

4.1.3 PlaceMail

PlaceMail [47] is a LBR service that runs on a mobile phone. It is a utility that helps in performing everyday tasks. It uses GPS to determine the users' location and deliver messages. Users can easily create and receive reminders such as task related events and so on. Before using the LBR, one has to generate the data such as add places in the list of places to be visited on a particular day-time and add corresponding reminder messages to the bookmarked locations.

One of the main disadvantages of the PlaceMail is lack of any social experience as the application does not involve any collaboration activity.

4.1.4 ARQuake

ARQuake [57] is a single player, AR version of well known game Quake. The players move around a virtual environment to perform some tasks and earn points. The physical space is modeled into virtual Quake level. The tasks include shooting monsters, collecting items and power-ups. A player has to wear head mounted display, haptic gun and other hardware equipments. ARQuake relies on the accuracy of GPS and digital compass for viewing orientation and marker-based computer vision for tracking the players in a virtual space. In contract to original Quake, where players move using keyboard in a desktop environment, ARQuake enable its players to freely move around in a physical environment and perform different tasks by wearing head-mounted displays (see Figure 4.3). Due to the use of head mounted displays, it makes difficult for players to play for long. This is one of the main disadvantages of this application.

Figure 4.3: Player dressed with head mounted display in ARQuake [57]

4.1.5 Human PacMan

Human PacMan [14] is a MMR game that has modified ARQuake into a multi-user game. Moreover, Human PacMan further extended arcade game PacMan with an AR adapted version that is played in a real city location. The idea is same as in the original game where a player has to collect all cookies in the digital space without get hunted by the ghosts. However, it has a contrast to the original game that ghosts are represented by other players who are trying to catch PacMan.

It is similar to ARQuake in a way that every player has to wear tracking system, head mounted displays and wearable computer systems. Players are given different motivation reasons such as power-ups, cookies and points to keep them running with full spirit. People can participate as PacMan, ghost or simply as helpers who play using the desktop version of the game. Players can communicate with helpers and central server using text messages and wireless connectivity. Due to the head mounted displays, the game length is kept short as it is difficult for the players to move with head-mounted displays and other equipments. Both GPS and inertial sensor data are used to calculate the precise location of the players.

Human PacMan also suffers from the network related disturbances so potentially affect the experience of the players. Furthermore game can only be played in an area where connectivity is strong. To minimize this problem, Human PacMan does not provide any other channels or alternatives such as audio channel.

4.1.6 Pac-Manhattan

Pac-Manhattan [2] is a large scale urban MMR game. Pac-Manhattan is a multi-player game based on classic 1980's PacMan game. One player dresses as Pac-Man and four others dress as ghosts (see Figure 4.4). They run around Washington Square Park at Manhattan where all ghosts make attempt to catch PacMan before it collects all virtual dots that are distributed evenly throughout the virtual gaming landscape. This game is played in a larger landscape having a matching virtual game area. Unlike other gaming solutions, it does not use GPS and wireless connectivity for tracking and serving information. All the players participating in the game cannot be directly tracked. Each player is assigned with a controller that acts as a communication source between the player and central control room. When players run on the physical track then they inform controller about their current location through voice calls. Central control room updates the position of every participant on the software map which is also broadcasted on the Internet. Central sever maintains the appearance of virtual dots as PacMan position changes on the map. Every player has to keep on talking with the controller to know each other's location, number of virtual dots left and so on.

In contrast to the ARQuake and Human PacMan, it did not use GPS for tracking players and wireless connectivity to serve the players. Pac-Manhattan considers both these techniques are susceptible to errors hence they rely on human controllers to judge the players' position and ensure concurrency between physical states of the game to the virtual game state.

Figure 4.4: Player dressed in blue and red while playing Pac Manhattan [2]

4.1.7 Mogi

Mogi [46] is MMR application that involves collecting and trading virtual items placed in the large physical area. It provides an interface running on a mobile phone for all the players (see Figure 4.5). Players can see detailed grid map of total area on which the game is played, position of the players and virtual items. Both the cell positioning system and GPS are used to track the location of the participants. It is a commercial game where players find virtual items and later trade them with other players to earn money. Players can also communicate and collaborate with each other using the interface of the application. This brings the MMR experience to its users.

Mogi is first of its kind multi-player, location-based and role playing AR game that promotes teamwork by the means of physically positioned targets. It accommodates all spheres of the gamers from social non-gamers to hardcore gamers as it is easy to start for new users, accommodating, no killing and no running type of game.

One interesting feature of the Mogi is that it arouses strong feeling of reality and connectedness which comes from seeing and being seen by others. It makes use of avatars, messaging, seeing other users and one hand play to create MMR experience.

Figure 4.5: Overview of Mogi interface [46]

4.1.8 Desert Rain

Desert Rain [40] is multi-player, MR game that requires heavy involvement from the players. All players set for finding some potential targets in the virtual environment. The targets are explained through names and photographs. The virtual environment is projected through water curtains and every player gets its own water curtain. This game is played in time critical environment where only 20 minutes are given to complete the assigned task. It is not a location based game so GPS, wireless connectivity and mobile phones have no role to play. Every player is demonstrated with their viewpoint projected on the rain curtain that acts as virtual screen. Players are equipped with headphone and microphone so that they can communicate with each other depending upon the locations inside the virtual screen (see Figure 4.6). Certain numbers of unseen helpers are present in the room where game is played in order to enhance the MR experience of the players. Continuous monitoring, intervention, listening and communicating with other players all are the parts of this MR game.

Desert Rain is an example of MR performance where art is combined with technology to blur the boundaries between the physical and virtual objects. This enables the players to re-evaluate the boundaries between the reality and virtuality. The use of rain curtains further intensifies the idea of obscurity and distortion of real events taking place in the environment.

One main disadvantage of Desert Rain is that it relies heavily on the production team which includes actors and invisible helpers which support the experience of the players by monitoring, intervening and motivating players.

Figure 4.6: (a) Player standing in front of virtual screen [40] (b) Player standing in Dessert Rain [40]

4.1.9 Co-Visiting

Co-visiting [13] is a MR application that enables the visitors of a museum to share their experiences. Three people can visit the museum simultaneously using shared physical-digital space. One visitor is physically present in the museum while other two visitors make use of virtual reality (VR) and web version of the application to participate in it (see Figure 4.7). The MR experience is produced by the use of headphone, microphone, PDA, ultrasonic location tracking system, 3D display and 2D maps. It provides different means of interaction through shared audio conversations, sharing information about the location,orientation and having common information space by the use of different interfaces.

Co-visiting [13] is interesting as it supports social aspects of a shared visit to a popular place like museums. The shared resources provided by the application enables the visitors to navigate in new places seamlessly. Collaboration, sharing of experiences and voice conversation brings a new social experience which is also appreciated by the users of the application. Furthermore, the application makes good use of the MR in supporting interaction between the participants at a distance. However, main idea behind this application is to support hybrid exhibitions as a group of physical, web and virtual reality visitors.

There are some disadvantages of the Co-visiting like - shared audio channel did not motivated the visitors to have conversations, participants making use of virtual reality are always at disadvantage compared to web and physical visitors, user face problems in building understanding with other visitors due to short time, navigation inside the place is easier for the digital users compared to physical ones due to the availability of number of different ways.

Figure 4.7: (a) Co visiting used in museum [13] (b) Co visiting on mobile [13] (c) Co visiting virtual reality [13]

4.1.10 Where On-Line Meets On-The-Streets (WLMTS)

Flintham et al. [18] described two MMR games where online participants collaborate with the mobile participants on the streets. The first one is *"Can You see Me Now? (CYSMN)"* which is a fast moving game having twenty online players that are chased by three runners across the map of the city. All the players and runners are moving through the actual streets but augmented view is created through the interface of the handheld display (see Figure 4.8). It motivates and engages the online players by providing them experience of a runner. There online actions also affect the events on the streets. The second game is *"Bystander"* that includes the search of an unknown person on the street where a local player takes this challenge to search the entire city in-order to find the target. The name and picture of the target is quickly shown to the player. An online player collaborates with the player in this search and guides them in this whole event. The second

game represents the scenario where action takes place in the physical world while the players sitting at distance participates digitally.

There has been growth in the MR games having online players which play in favor or against to those on the streets. Unlike other AR application, it did not require any wearable computer or head mounted displays. It includes the use of handheld computers having AR displays to play games.

This application has one interesting contribution that in general, MMR applications overly rely on the GPS due to which users' experience is hindered and many times GPS errors lead to frustrations among the user community. To resolve these problems associated with the GPS and other location tracking tools, it recommends alternate channels such as audio talk, ambient audio, local knowledge, trust and use of extended interfaces.

Figure 4.8: (a)Player while playing WLMTS [18] (b)Overview of WLMTS equipment [18]

4.1.11 TimeWarp

TimeWarp [29] is outdoor MMR game for exploring the history of a particular place in a temporal and three dimensional spaces. Unlike other location aware MR gaming solutions, TimeWarp combines the gaming experience and education with MMR applications. The game is based on the legend of the Heinzelmännchen of Cologne where Heinzelmännchen have disappeared and goal of the game is to bring them back. TimeWarp aims to fuse the physical and virtual elements to create illusion that players are present in different time periods.

It uses ultra-mobile PCs (UMPCs) which is a handheld information device that is equipped with a variety of sensors, capable of motion detection. GPS and inertial sensors are used for detecting position and orientation of the players (see Figure 4.9). One UMPC is used by the players to navigate through the city and find their target locations while second UMPC provide lens to view various time periods.

In contrast to Human PacMan, it makes use of certain locations that are historically and culturally significant so it is more closed related to the environment where this game is played. TimeWrap also suffers from inaccurate tracking and GPS errors for which it uses visual feedback, a graphical element in the head-mounted display for receiving tracking updates.

Figure 4.9: Player while playing TimeWarp game [29]

4.2 Feature Triangle

The applications described throughout this chapter make use of various techniques such as location awareness, social connectivity, gaming and collaboration for creating MMR environment. In order to distinguish between the different approaches, I used a simple comparative analysis tool called Feature Triangle (see Figure 4.10).

During the literature review of existing AR/MMR applications, I did not found any source except Olsson et al. [53] describing *"How to design UX for any MMR application"*, *"What factors affect the UX of any MMR application"* and *"What kind of features any future MMR application should*

support". However, Olsson et al. [53] has partially addressed first two questions. Due to these reasons, I rigorously analyzed each and every application from design, feature and hosted content point of view. Furthermore, this is also one main reason why I chose to develop a framework of my own instead of taking any of the existing generic UX models. This framework presents the different aspects that I identified from the applications. In the middle of this review process, I figured out three broad features as *"Social interactions"*, *"Design"* and *"Experience"* which are present in different applications. These broad features form the vertices for my feature triangle.

Feature triangle helps in mapping each application based on their properties and functionalities into a three-dimensional feature space. The dimensions of this feature space are derived from the research questions (see Section 1.3) of this thesis and therefore they are aligned with my main objectives.

As explained in the research motivation (see Section 1.2), the title of the thesis contains three keywords as *"People, Design and Experiences"*. The three vertices of the feature triangle also represent these three keywords in the title of the thesis. This connection between the title of the thesis and feature triangle can be explained as - I found that people, design and experience aspects affect the acceptability of any new technology or concept while reviewing different AR/MMR applications. The vertices of the feature triangle can be explained as -

1. **Experience:** Represents the experiential aspects of the application. *"Experience"* is defined as *"UX generated when a user interacts with a product individually or socially via an interface"*. This definition for experience is same as I defined in the chapter 3 (see Section 3.5). UX refers to hedonic aspects such as pleasure, beauty and arousal and pragmatic aspects of use, i.e. utility but as in thesis, I am more interested in the hedonic side of UX so *"Experience"* also refers to the emotional and hedonic elements of UX associated with the use of MMR application. UX of MMR application should be designed in order to give pleasing emotional response to its users.

2. **People:** Represents social interactions are facilitated by the application. Social interaction refers to a process where people respond or act towards each other. The keyword *"People"* refers to the social aspect of MMR. It is found that having factor of social engagement where people play in favor or against each other in MMR application can help in user adoption of MMR.

3. **Design:** Represents the design features of the application. *"Design"*

refers to the potential design of MMR application that enhances the experience of MMR users and provides engaging effect during interaction.

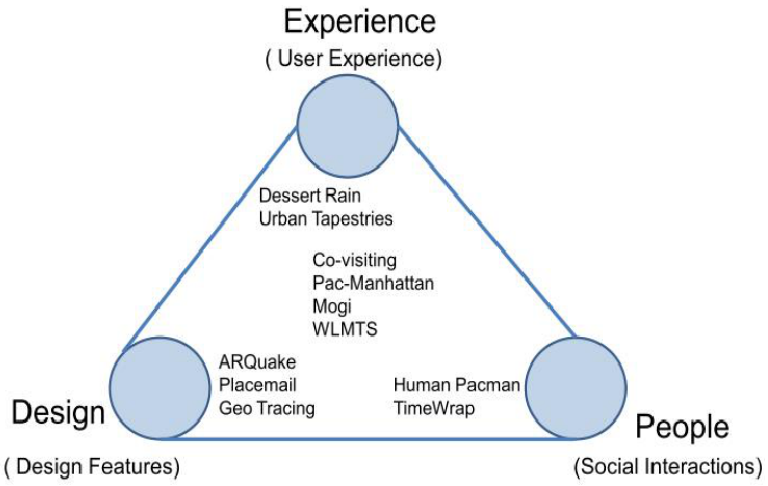

Figure 4.10: Feature Triangle

Dimensions of the resulting feature triangle (see Figure 4.10) are defined above. I placed all the above discussed applications (see Section 4.1) in the feature triangle. If an application is positioned at the end-points of the triangle then this indicates that only that corresponding dimension is utilized. The main contribution of having feature triangle kind of framework is that it gives a brief overview on different features or vertices are utilized by different applications.

Urban Tapestries do not include any *"People"* aspect as it is used individually like other LBRs. It makes use of GPS and internet connectivity for serving maps, media annotations of the tracks. Moreover, it does not provide any new design or feature compared to other common LBR systems. In addition, Desert Rain is quite similar. Although Desert Rain is a multiplayer MR game but it lacks *"People"* contribution because players do not play in favor or against each other at any time of the game. It also lacks in any *"Design"* as the game is heavenly orchestrated by invisible actors and helpers. Due to these reasons I placed both these applications at *"Experience"* vertex of feature triangle as both the applications focus on experiential aspects but lacks in people and design aspects.

Human PacMan is a multiplayer game where players chase each other in the MR environment so it involves a *"People"* aspect where players tie up in groups in order to achieve common goals during the game. It makes use

of GPS, text messages and other wearable head mounted systems in order to achieve the AR environment. Similarly TimeWrap is also an outdoor multiplayer MMR game where players explore the history and culture of the place in MR space. Both the applications utilize the social feature that is why I placed both of them at *"People"* vertex of feature triangle. Due to inaccurate tracking, GPS errors and lack of any *"Design"* contribution, both these applications lack *"Experiential"* aspects.

Mogi, Pac-Manhattan, WLMTS and Co-visiting are multiplayer MMR games that are played using mobile phone interface. All of these games do not make use of heavy head mounted displays instead mobile phones are used hence participants' experiential aspects are enhanced. This fact is further strengthened as none of them makes use of GPS tracking and wireless network connectivity. Mogi uses mobile phone network positioning to complement GPS based tracking; WLMTS uses alternate channels such as audio talk and ambient audio, Pac-Manhattan makes use of human controllers to determine the players' position and Co-visiting uses shared audio channels for location tracking. This concludes that Mogi, Pac-Manhattan, WLMTS and Co-visiting have significant *"Experiential"* aspects. Mogi, Pac-Manhattan, WLMTS and Co-visiting involve certain factors that motivate players to communicate and collaborate using mobile interface. Those factors are collecting and trading of virtual items, messaging, live chat and virtual avatars. This confirms significant *"Design"* contribution. Furthermore, all these applications are multiplayer and involve collaborating and competing with each other. This confirms significant *"People"* contribution. I placed Mogi, Pac-Manhattan, WLMTS and Co-visiting in the center of feature triangle.

ARQuake, PlaceMail and GeoTracing are single player applications hence they lack *"People"* contribution in form of collaboration or competition. ARQuake involve collected points, virtual gaming maps and shooting monsters, PlaceMail and GeoTracing makes use of GPS for location tagging and creating reminders. Hence ARQuake, PlaceMail and GeoTracing possess some *"Design"* contributions. GeoTracing suffers from GPS errors and wireless fluctuations, ARQuake includes head mounted displays and other heavy hardware equipment for playing, and PlaceMail lacks in experiential aspects as it is an ordinary LBR. These demerits conclude that ARQuake, PlaceMail and GeoTracing lack *"Experiential"* aspects. I placed ARQuake, PlaceMail and GeoTracing at *"Design"* vertex of the feature triangle.

Based on the investigation of related applications, it is clear that only few of them make use of each of the dimensions. Thus, it is important to emphasize that not all of applications aim to facilitate social interactions and UX which is the main objective of this work. Moreover, I feel applications that are placed in the center of the triangle, meaning exploiting each and

every dimension of the feature triangle are competent and have potential to be the market leaders.

4.3 Summary of the Requirements for Future MMR prototypes

This section concludes by describing seven requirements that have been identified in the AR and MMR applications that I described in the beginning of the chapter. These requirements will serve as building blocks for my prototypes and scenarios. The comparison of these requirements to the applications discussed above is presented in Figure 4.11.

- Multi players - Eight out of eleven applications involves multi-players as it enhances the interaction between the players so having multiple players can increase the social experience of the participants.
- 2D maps- Eight out of eleven applications had 2D maps as the primary way of showing the AR/MMR information on the screens of the devices.
- 3D view - Only three applications made use of 3D view of the information displayed on the screen. 3D view enhances the AR view of the user as virtual environment is imposed on the physical objects.
- Geo-Tagging - Only two applications enable their users to perform geo tagging. By geo-annotation I refer to an activity where players can create their own location based content by uploading media information to a location or track in the map. This information is can be available for all the present and future players.
- Location based content - Nine applications serve location based content to the players. By location based content I refer to media content such as textual, photo, video and audio that is triggered when the player reaches some destined position.
- Playfulness - Playfulness refers to an enjoyable experience that involves some kind of reward or motivation for the participants of any product or service. During the application review process, I found an interested fact regarding the application design that almost all the applications involve some kind of playful experience like collecting points, power-ups, finding treasure or hidden things, fighting with ghost and so on. This playful experience arouses some kind of motivation among the players and helps in maintain an engaging effect with the users. I

consider an application possess playfulness if it includes a motivational element that brings a playful experience.

- Audio channel - Four applications used audio conversations between the players as an alternate channel to tackle errors in GPS tracking. Audio channel solves the problem due to GPS errors to an extent. Moreover, it enhances the social and overall experience of the players.

Games	Multiplayer	3D view	2D map	Geo Tagging	Location Based	Playfulness	Audio channel
Urban Tapestries			X		X	X	
GeoTracing			X	X	X	X	
PlaceMail			X	X	X		
ARQuake	X	X			X	X	
Human Mahattan	X	X			X	X	
Pac Mahattan	X		X		X	X	X
Mogi	X		X		X	X	
Dessert Rain	X					X	X
WLMTS	X		X		X	X	X
Co-visiting	X	X	X			X	X

Figure 4.11: Comparison of requirements to AR/MMR applications

Overall, an application which is capable of supporting MMR environment by making use of different inbuilt mobile phone sensors, combining it with design features and exploiting social interactions may act as a means for enhancing the UX of future applications. Overall this chapter gives a brief description of the theoretical understanding behind the AR and MMR applications covering social and experience aspects. Furthermore, empirical contribution in the form of feature triangle and comparison table forms the basis for the remaining chapters. The understanding gained from the feature triangle and summary of the requirements is used in performing the empirical phase of UCD methodology in Chapter 5.

Chapter 5

User Centered Design in MMR

This chapter describes the UCD methodology as an empirical part of this thesis. Different phases of the UCD process are described with enough explanation in a chronological order. This is done so that the study can be repeated with similar users group to achieve similar results.

MMR is a futuristic and novel technology concept so it is important to choose a correct platform that complements its basic nature. UCD serves this purpose as it involves user throughout the development process of any technology or concept in question. A total of 15 users participated and are interviewed in the different phases of UCD. The results obtained through the different phases of this methodology are presented and discussed.

In this chapter, first the user study is reported in detail by providing an outline about the different phases of the UCD study in Section 5.1, Focus group interviews and questionnaire are conducted for user data collection (see Section 5.2). Furthermore participant profile, structure of focus group sessions and analysis of the gathered data is presented in Section 5.2.1-5.2.3. In Section 5.3, main results of the study are presented in detail. After this an alternative method for data collection called *Lost foreigner* and its results are being shortly summarized in the Section 5.4. *Lost Foreigner* is important contribution of this thesis as it helps in comprehending the understanding on users' behaviour while having interaction with any potential MMR application (see Phase 5 of Section 5.1).

5.1 Phases of the Study

The end goal of carrying an extensive UCD study is to include the end users' aspect into the development of MMR application. Different phases behind the UCD are discussed below. I paid emphasis to fulfil the main research

goals behind this thesis (see Section 1.3) at every phase of the UCD study. The different phases behind this UCD [4] are -

- **Phase 1:** Determine user needs and expectations for MMR applications
- **Phase 2:** Design and develop prototypes for MMR concept based on the user research
- **Phase 3:** Iterate and re-design the prototype based on user comments and suggestions
- **Phase 4:** Evaluate the prototype against user needs
- **Phase 5:** Comprehend understanding on users' behaviour while having interaction with the MMR application

The emphasis is given to fullfil all the above defined phases throughout the UCD study. However, the focus between the above phases kept varying due to different study methods. For example, first phase is focused during focus group interviews; second and third phases are focused while performing paper and functional prototyping. Fourth phase is focused while testing the improved prototypes with the test participants. Final phase is considered in *Lost Foreigner* as an aditional method for data collection (see Section 5.4). Overall first phase is heaviest among all the other phases. Furthermore the main focus of this empirical UCD is on the first phase while other phases helped in the designing of prototypes and proofs of concept to some extent.

The ISO 13407 [4] definition (see Section 2.1) is followed as a guiding source for performing the entire UCD process. In the very beginning of the UCD, extensive field study is decided as a starting point. Ideally field studies should involve exploration of the user needs by studying users in their real working environment but in case of MMR this is not only difficult but nearly impossible to perform. First, MMR is a futuristic concept which is currently used by few users so finding real users of MMR and making use of the service in the real environment is hard to realize in practice. Second, usage of the mobile phones is heavenly dependent upon social and physical environment for example different users makes use of their mobile phone in different ways, some prefer to use them only when they are travelling or doing shopping while others may like to use them every now and then. Furthermore, MMR involves very diverse tasks.

The field study is planned keeping in mind the obvious concerns like getting errors in the study results by performing studies in unnatural environment and testing the prospective users by incorrect research methods.

Furthermore, the content of the study is validated by the instructors of the thesis in the very beginning. Four different focus group discussions are conducted in order to gain a comprehensive look at the various users' needs and expectations as mentioned in the first goal of the UCD (see Section 5.2). After performing the focus interviews, the resulting data is consolidated using affinity diagramming (see Section 5.3). This helped in better understanding user needs and expectations for MMR. Later, design of the concepts and iterations are made using paper and functional prototyping as per third goal. Both these prototypes are later evaluated against the user needs as mentioned in the fourth goal.

I practiced triangulation research principle (see Section 2.2) for data gathering process. The methods selected for the data gathering are combination of qualitative and quantitative research methods i.e. focus group interviews for collecting qualitative feedback on MMR and questionnaire for gathering quantitative results on users expectations and needs from MMR. Mostly qualitative data is generated with some elements of quantitative data. Triangulation research principle helped in finding inconsistencies and conflicts in the study results. It enabled me to widen the scope of the study and view the MMR from multiple dimensions. Furthermore, this lead to valid and exhaustive interpretation of the crucial findings and results that can be easily generalized without losing the original value.

At the time of planning of UCD process, there is a concern regarding the validity of the opinions to be gathered during the focus interview. User needs are based on the users' current behaviour and general opinions. Users' attitude and values can possibly influence their statements. It becomes important especially in the matters involving ethical and social issues. Furthermore, it is a well known fact that focus interviews can elicit only subjective opinions [60]. This could also heavenly affect the design of the MMR prototype and possibility lead to its failure in the market if it does not satisfies the mass users. In order to minimize this potential bias of subjectivity in the users opinions, two important measures are taken. First existing methods of user research are complemented by one additional research method called *Lost Foreigner* (see Section 5.4) devised by me. Second, UCD process is made highly iterative for example prototyping is performed thrice involving different users every time.

5.2 Focus Group Interviews

During this project, I conducted four different focus group sessions with 15 participants (see Section 5.2.1). Focus group interviews are combined

with questionnaire survey, visual storyboard and scenarios. Questionnaire survey helps in collecting quantitative feedback from participants while visual storyboard and scenarios acted as stimuli for the participants during focus group sessions. Furthermore the use of different stimuli's helped participants in understanding the MMR context in a realistic but experimental setting.

5.2.1 Participants

	Group session 1	Group session 2	Group session 3	Group session 4
Male	2	4	0	2
Female	1	3	3	0
Youngest	24	23	31	18
Oldest	28	30	44	42
Average Age	26	25	36	30

Figure 5.1: Background information of the participants

The background information of the participants is presented in the Figure 5.1. First session consisted of two males and one female having age ranged from 24 years to 28 years. All three of them have IT background and they can fairly well do programming. Nationality wise their representation is Portuguese,Indian and Montenegrin respectively. Second session had four males and three females having age ranged from 23 years to 30 years. All seven of them have IT background and they can fairly well do programming. Nationality wise their representation is 3 Finnish, 2 Indian and 2 Bangladeshi. Third session had only three females having age ranged from 31 years to 44 years. All three are Finnish nationals having no programming experience but are daily internet users. Fourth session consisted of only two Indian females having age ranged from 18 years to 42 years. They do not possess IT background and use internet on weekly basis. Participants' age ranged from 18 years to 42 years with Mean = 28.06 years and Standard Deviation(SD) = 4.43. Ten participants are studying at Aalto school of technology in different science streams, one participant is a high school student and four participants are working in different servicing companies in Helsinki. I aimed at technologically oriented people because they are the early adopters or lead users for any new service or product. I believe that lead users can provide

me further insight on the possible use cases of MMR technology and concept. Apart for the early adopters, lagers or slow adopters are also included into the study so as to understand their needs and expectations from MMR.

5.2.2 Structure of Focus Group Sessions

I divided every focus group session into three different phases. The reason behind keeping the same format for each of the group session is - I wanted to combine the observations from each of the group sessions at the end so naturally, keeping same study setting is important for such kind of experiments. Group sessions are divided into following -

- **Phase one:** Warm up and introduction, 15 minutes
- **Phase second:** Group discussion, 45 minutes
- **Phase third:** Filling the post questionnaire, 10 minutes

Phase One
In the warm up and introduction phase, test participants are introduced with the test environment and they are asked to sign the consent form for participating in the user study. In the consent form, it is mentioned that participants' identity will be not revealed except their age and technical orientation. I promised to keep their names anonymous and such incidents will be avoided that can directly or indirectly lead to disclosure of participants' personal information and opinions expressed during the study. After signing the consent form, participants are asked to fill the background questionnaire(see Appendix A.1). Background questionnaire contains eleven questions related to the technical orientation, motivation towards using technology and other aspects related to their daily routine life. Background questionnaire results are analyzed and presented below.

Background Questionnaire
Figure 5.2 presents the summary of the results from background questionnaire (BQ) filled by the 15 participants (N=15) before the focus group discussions. The background questions are *"BQ1 - technology plays important role in my daily routine"*, *"BQ2 - use Facebook or other online social networks for getting updates and sharing information"*, *"BQ3 - useful that my friends know my location and what I am doing"*, *"BQ4 - share information on blogs and websites to help people if my identity is kept anonymous"*, *"BQ5 - knowing about discounts/offers related to places to eat, shopping, travelling, etc"*, *"BQ6 - difficult to look for information when I am visiting unknown cities or*

different countries due to language barrier", "BQ7 - pay if someone can assist me when I am visiting a place that I have never been to", "BQ8 - concerned about privacy and do not want to share anything with the strangers", "BQ9 - worried about my personal information spreading in the web and getting into the wrong hands", "BQ10 - share information related to discounts and offers with my friends" and *"BQ11 - rating and recommendations for visiting places to eat/shop/travel as important".*

Majority of the participants consider technology as important in their daily routine (Mean = 4.47, SD = 0.83), use Facebook and other social network (Mean = 4.07, SD = 1.22), interested in knowing about discounts and offers (Mean = 4.13, SD = 0.74), like to see rating and recommendation for visiting places (Mean = 4.0, SD = 0.93), sharing information on discounts and offers with friends (Mean = 3.53, SD = 1.25), sharing information on blogs and websites anonymously (Mean = 3.8, SD = 1.32), difficult to look for information due to language barrier (Mean = 3.93, SD = 1.03) and worried about personal information spreading on web (Mean = 4.13, SD = 1.13). Participants are neutral about, privacy disclosure (Mean = 3.2, SD = 1.01), paying someone who can assist in visiting new places (Mean = 3.13, SD = 1.06) and sharing own location information with others (Mean = 2.23, SD = 1.18). After answering the questionnaire, participants are asked for

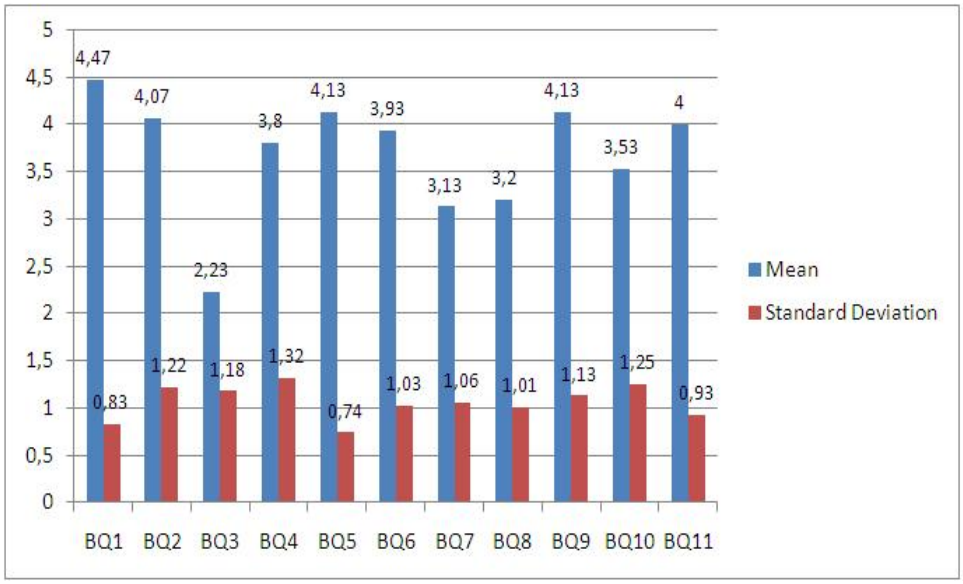

Figure 5.2: Results from Background Questionnaire (N=15)

permission to audio record the discussion during focus group. However, in the consent form and invitation email, it is explicitly mentioned that discussions

will be audio recording but after the completion of the thesis, all kinds of audio recordings will be destroyed. I used recording functionality available on Nokia N900 phone for recording all the interviews. Approximately five hours of interview material is gathered for the transcribing and post processing. In addition to the audio recording, important observations are noted during and after the group sessions. One additional recording is performed on my laptop in order to avoid any possible technical failure of the mobile phone. Voice qualities of both copies of recording are found similar during the transcribing process.

After signing consent form and background questionnaire, participants are introduced with the MMR concept by showing two videos depicting MR and MMR use cases. First video is of 2.24 minutes in duration and it presented the concept of MR using magic lense. Magic lense is smart computing device from where a user can perform all kind of things that he or she can do through a laptop. Magic lense is tool to access digital information augmented on different physical objects. Second video is of 1.52 minutes in duration and it presented the concept of MMR using a smart mobile phone application. User can create virtual flowers on the street view, tag icon on the buildings and associate virtual things with any real object. Both the videos helped me in making the participants familiar with the MMR concept. I used Sony BRAVIA 60 inch LCD TV 1080p for showing the videos in a room located on the second floor of Department of Computer Science and Engineering, Aalto University.

Phase Two

After showing the introductory videos, I started the second phase of group discussions by showing three different scenarios of the MMR in one at a time sequence on LCD TV screen. Participants are given one scenario at a time on printed paper as well as shown on TV screen. Participants read the scenario (100-200 word length) and then I initiated the discussion on it. The discussion is kept free flow and majority of the participants are extrovert in discussing so I did not felt the need to interrupt or extend the discussion process (see Appendix A.2). In Figure 5.3, group discussion questions are presented. It contains 13 broad themes on which I had 45 minutes of discussion with each of the four focus groups. These 13 questions are selected keeping in mind the phases of this study (see Section 5.1) and research questions behind the thesis (see Section 1.3). During the review of AR literature, I came up with an idea of using MMR in solving the problem of language barrier. I found that travellers often face problems in finding places and communicating with people when they travel to non-English speaking countries. Furthermore, during review process, I had an impression that so far MMR

	Group Discussion Questions
Q1	What do you think this technology/service is useful or not?
Q2	What do think about the benefits from this kind of technology/service?
Q3	How you fit this technology/service in your life?
Q4	What are the main strengths of this technology/service in your point of view?
Q5	Are you interested in using this technology/service? if yes then why? if not then what is the reason?
Q6	If this technology/service is paid then will you still use it in your daily routine?
Q7	What do you think is there any risk of using such kind of technology/service?
Q8	What do you think about privacy issues related to this technology/service?
Q9	Where you think this kind of technology/service will be mostly used?
Q10	Apart from the shown scenarios where would you like to you this technology/ service?
Q11	Is there any other use of this technology/service in your daily routine?
Q12	Do you want to see something different then what is shown in the scenarios?
Q13	What are your suggestions on this service and its use?

Figure 5.3: List of the questions asked during focus group sessions

technology has been utilized from leisure, gaming and hobby point of view. However, I consider that mass adoption of MMR is only possible if it becomes a utility in the daily routine of the users. Keeping in mind the above listed thoughts, I created my own three scenarios which I tested during the focus group discussions. The first and third scenarios are partially influenced by Olsson et al. [53]. These scenarios are as follows-

1. First scenario depicts a tourist in Paris who can only speak English and a first time visitor to France. It represents the situation of a tourist in an unfamiliar context.

2. Second scenario presents the use of MMR application in a country where a user faces problems due to language barrier for example China.

3. Third scenario represents discount and offers information in local Helsinki.

The contexts shown in these scenarios are chosen keeping in mind two facts namely 1) all participants of focus group discussion are living in Helsinki for more than two years 2) Participants are familiar with the places shown in these scenarios. This kind of selection has helped me in involving participants in a motivating fashion where participants feel like this study is for their own benefit.

Scenario 1: Tourist in Paris *"You are new to Paris and a first time visitor. Before landing in Paris, you have searched for some of the famous places in Paris like Champs-Elysées, Charles de Gaulle and Eiffel Tower on internet. You have decided to roam and visit places by your own because of your adventure loving nature. You want to explore by your own so do not want to take taxi, train, etc. You started walking by following the map but after walking 15 minutes you are lost somewhere. The crowd cannot understand your language, no one speaks English. You tried GPS of your mobile to locate place but most of the names are in French hence you have hard time in getting help from native people around you due to different style of speaking French names. Before visiting any place, you would like to see comments by other visitor, places to eat and drink around. You have started MMR application from your mobile. Its magic lense shows augmented digital information in the form of icons. You started following these icons. It shows you important places, spots, monuments on the way so that you don't miss anyone of them. The application also shows information such as latest happening in that area and most importantly your all time assistant".*

After presenting the scenario, participants are asked to think aloud and consider a situation if they are standing some distance away from Eiffel tower and viewing it through their MMR application (see Figure 5.4). After a while, MMR application shows user generated information tags on the Eiffel tower such as - *"You can buy souvenir here"*, *"14 euro price for 3rd floor"*, and *"Average time for reaching 3rd floor is 1 hour and 30 minutes"*. After

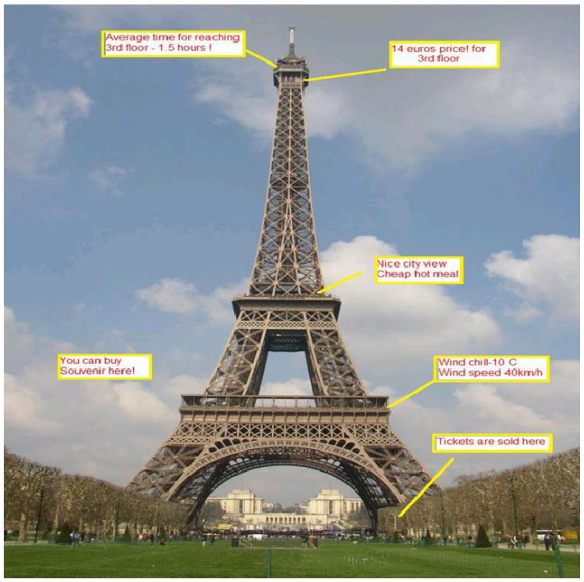

Figure 5.4: Eiffel tower scenario having information tags in MR view

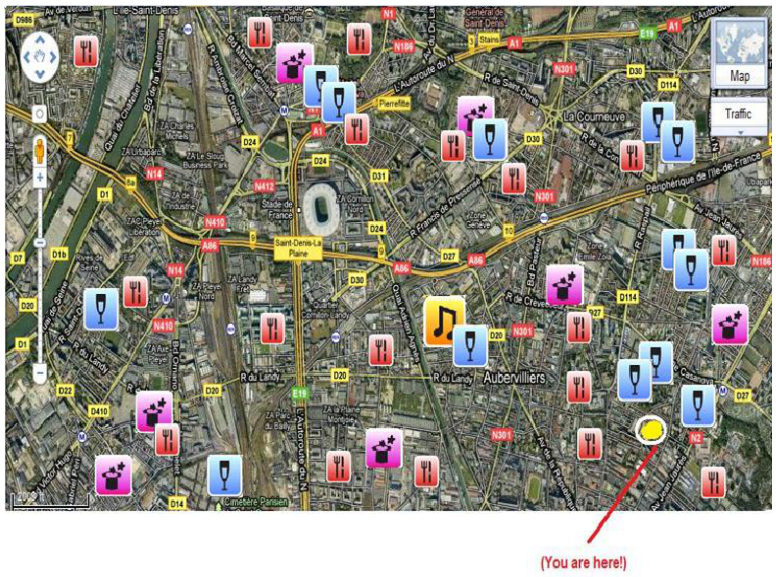

Figure 5.5: City of Paris map having digital icons in MR view

showing the Eiffel tower scenario, map view of Paris city is shown to the participants. They are asked to think aloud on a situation that you want to visit some restaurant or bar then MMR application displays icons on the map view (see Figure 5.5). Every icon shown in the scenario has some particular associated meaning to it.

Scenario 2: Language Barrier *"You are first time visiting China and before coming to china you learnt from some of your friends that hoardings on the streets are often in Chinese. It is lunch time and you are on a busy street in Beijing. Suddenly you noticed that everything is written in Chinese as shown in the picture. You tried to take help from people near you but it seems no one can communicate in English. You feel hungry but cannot locate any place to eat or drink because all sign boards are in Chinese. You have started MMR application from your mobile. Its magic lense shows augmented digital icon in the form of icons (see Figure 5.6). Finally, you have found a cheap and best place to try Chinese cuisines!"*

Scenario 3: Discounts and Offers *"You want to buy some groceries and snacks but want to spend less money. You are a kind of person who is always looking for discounts and offers. You went to K market which is very huge and you are lost in this big place. You failed to find any suitable information that shows sale/offers/discounts. The shopping center has old*

Figure 5.6: Street view in China having augmented digital icons in MR view

employees who are not comfortable in speaking English. You have started MMR application from your mobile. Its magic lense shows augmented digital information on the grocery items such as Bumper sale, Exclusive sale and Best buy as shown on the screen. You quickly follow those augmented signs and grab your groceries as they fit your budget".

After presenting the scenario, participants are asked to think aloud and consider a situation if they are standing outside kamppi Mall at Helsinki. They are asked to believe that it has become difficult for them to choose a place where you should go like for shopping, eating or watching movie. After a while, you started viewing whole kamppi landscape through their MMR application. MMR application now started showing user generated digital information tags that are annotated with different places and buildings (see Figure 5.7). This scenario contains information such as *"Promotional offer at some bar - One free beer with 8 euro meal"*, and *icons for restaurant, movie.* Within the discounts and offers scenario, one more use case is tested. Participants are asked to think aloud on a situation when they have recently visited Finnish Parliament and an old museum nearby. You found that museum is worth watching and having no entry fee for next two weeks. Furthermore, you consider that Finnish parliament is also a nice place to be as it has no entry fees. You decided to share this useful information with your friends. You started MMR application and added information tag displaying *"Nice Place, no entry fees¡'* However, when you started adding information tag on museum you found that it already contains an old tag displaying *"Old museum, worth watching, 3 euros entry fee!"* You decided to edit this information and display *"No entry fees till Sunday!"* (see Figure 5.8).

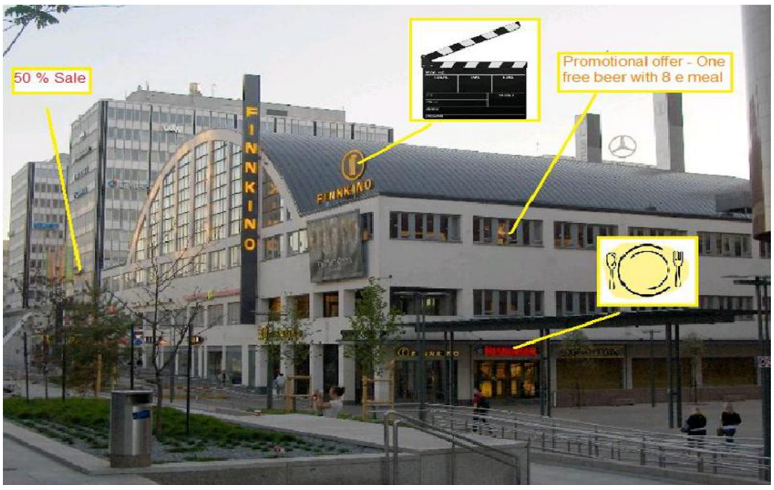

Figure 5.7: Outside view of Kamppi Mall displaying MR content

Figure 5.8: Finnish Parliament and old museum displaying MR content

Phase Three

After having discussion on the three different shown scenarios, participants are asked to answer the post questionnaire (PQ) (see Appendix A.3) related to the study (N=15). The post questionnaire is introduced in order to evaluate the expectation of the participants from the MMR technology and use cases that are introduced during the focus interviews. The nine questions covered in this questionnaire are *"PQ1 -ease out cognitive load (load on the human memory)"*, *"PQ2 - become smart traveller"*, *"PQ3 - become*

smart shopping customer", "PQ4 - become eco-friendly by avoiding paper printed offer/discount pamphlets", "PQ5 - gain more information about my surrounding environment", "PQ6 - fulfil my needs of the daily routine", "PQ7 - bring liveliness to my life by evoking memories and emotions", "PQ8 - add value to existing mobile services" and *"PQ9 - definitely use MMR if it comes into existence"* .

Figure 5.9 presents the summary of the results from post questionnaire filled by 15 participants after focus group discussions. Majority of the participants are positive that MMR can help in becoming smart traveller (Mean = 3.9, SD = 0.8), easing out the cognitive load (Mean = 4.0, SD = 0.78), becoming smart shopping customer (Mean = 3.5, SD = 0.74), become eco-friendly by avoiding paper printed offers and discounts (Mean = 3.8, SD = 0.94), gaining more information about surroundings (Mean = 4.6, SD = 0.51), add value to existing mobile services (Mean = 3.8, SD = 1.33), bringing liveliness to personal life by evoking memories and emotions (Mean = 3.4, SD = 0.91). Participants agreed that they will definitely use MMR if practically realized (Mean = 3.8, SD = 0.88). Participants are neutral that MMR application can fulfil their daily routine needs (Mean = 3.1, SD = 1.44).

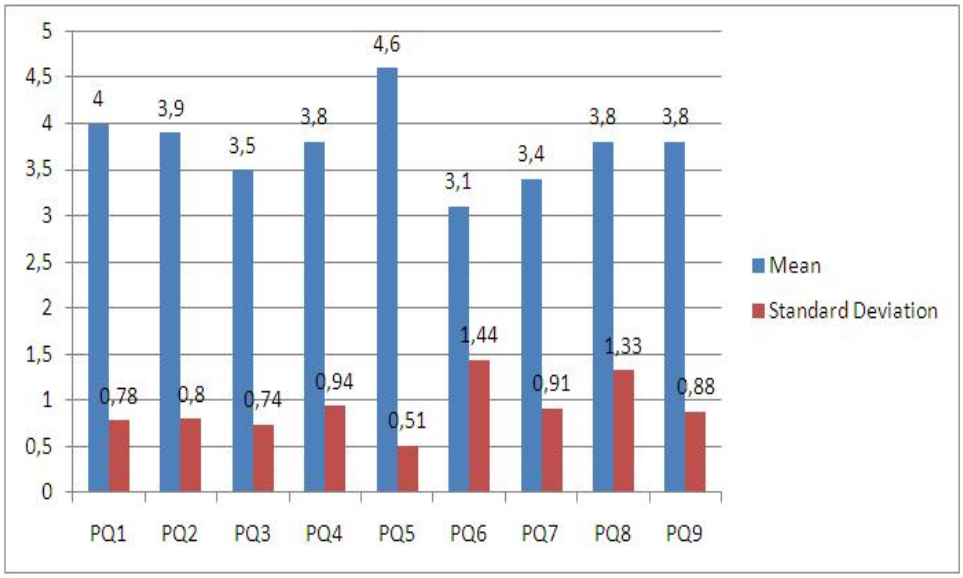

Figure 5.9: Results from Post Questionnaire (N=15)

5.2.3 Analysis

In this section, analysis process is described. After having four different focus interview sessions, about five hours of audio conversations are recorded. All the audio recordings are coded and transcribed word by word. It took total of 18 hours in the whole transcribing process. The observation notes made during four different focus interviews are also added to the interview transcripts. These written notes and transcripts act as the building blocks for affinity diagram [49].

Affinity diagram is based on the user observation and interview notes, representing different issues, problems, needs and expectations across a hierarchical diagram in order to reveal the scope of the actual problem [9]. The aim of affinity diagram building is to keep completeness of the MMR user studies and understand the users' needs and expectations from MMR concept.

Affinity diagrams created by single member do not yield the required results as stated by [49]. Due to this reason, affinity diagram process involved three students that include me and my two other friends.

Affinity diagram building start by first writing one observation at a time on post-its (sticky note in my case). Later, reading aloud one observation at a time. This helped in interpreting initial ideas behind that particular notes and making groups of them. The arrangement of notes in form of post-its is made one at a time which is both useful and time consuming at the same time (see Figure 5.10) [10]. Individual post-its are arranged into

Figure 5.10: (a) I am creating post-it's (b) I am creating affinity diagram

groups according to similarity of the underlying content. These groups are

labeled using colored sticky notes where every color represents different level in hierarchy. Groups are given unique and descriptive headings and these headings are later used to further organize them into larger groups. This process can be repeated until all the post-its are arranged and structure of the affinity diagram is organized well enough [49]. I used pale yellow for level one, green for level two, dark yellow for level three and dark pink for level four in the hierarchy. The groups are later combined with other groups in order to obtain final cluster of observations in a hierarchy of up to four levels (see Figure 5.11). The organization is altered several times during this building process due to the absence of predefined group heading. Avoiding predefined categories while perform affinity diagram is one of the recomended pratices in user data analysis. [10]

Figure 5.11: (a) Organizing of post-its into groups (b) Final representation of the post-it hierarchies

Building diagrams requires considerable effort, time and space. Total of 468 post-its are made during affinity diagram process that took approximately 30 man hours. Two other students participating in affinity diagram are available only on weekends so affinity diagram process took place at Aalto Venture Garage during weekend. This place does not have walls where sticky notes can be attached so instead I made the use of 3 tables having 2.5m x 1.5m as dimensions. Affinity diagram is performed in two sessions having approximately equal duration of 5 hour. In the beginning of affinity diagram everyone is enthusiastic but slowly it turned out of be tiring and effort taking task. This could possibly add bias into study results and affect the study as a whole. Moreover interpretation requires both patience and energy. In order to handle issues related to participants fatigue and performance, I decided

to perform affinity diagrams in two phases. The final level affinity diagram gives review results and helpful in the idea creation process. Overall affinity diagram took long time in completion but the user study results are many times worth the spent effort.

5.3 Results

After completing affinity diagram process, a total of 36 broad categories from the user data are prepared. These 36 categories are reviewed and analyzed from different perspectives such as implementation, concept level, design and business. After analyzing these 36 categories, I prepared eight main broad themes keeping in mind the above listed perspectives for any prospective MMR application (see Figure 5.12). It is interesting to mention that all the findings are similar to results given by Olsson et al. [53]. Out of the eight broad themes about seven are similar to the previous research carried by Olsson et al. [53] while one new theme is discovered on "Restrictions in using MMR". The eight main design themes are explained as follows -

5.3.1 Need for customization

The availability of too much information confuses users, so the MMR application should support customization of information. Customization or personalization is regarded as one of main user need from any future MMR application. All participants emphasised this need while mostly participants correlated customization with information search, retrieval and filtering. Participants mentioned customization in several different forms such as - preference based search, search based on categories like prices, distance and ratings and customization of the projected information on their mobile screens. Some of the participants have mentioned - *"If the information is just flooded on my screen that I won't like, instead MMR give some customization so that I can view only those information tags that are important for me(group session 4, female 42)"*, *"Ratings and recommendations are generally fake so it is important to know the background of the people who gave those ratings and recommendation like if I want to buy some shoes for my mom then I would like to see rating and suggestion by Finnish females having age above 50 (group session 3, female 31)"*

Overall customization is recognised as an essential need by all participants. Future application should support personalization on several levels so that it fits most of the users group.

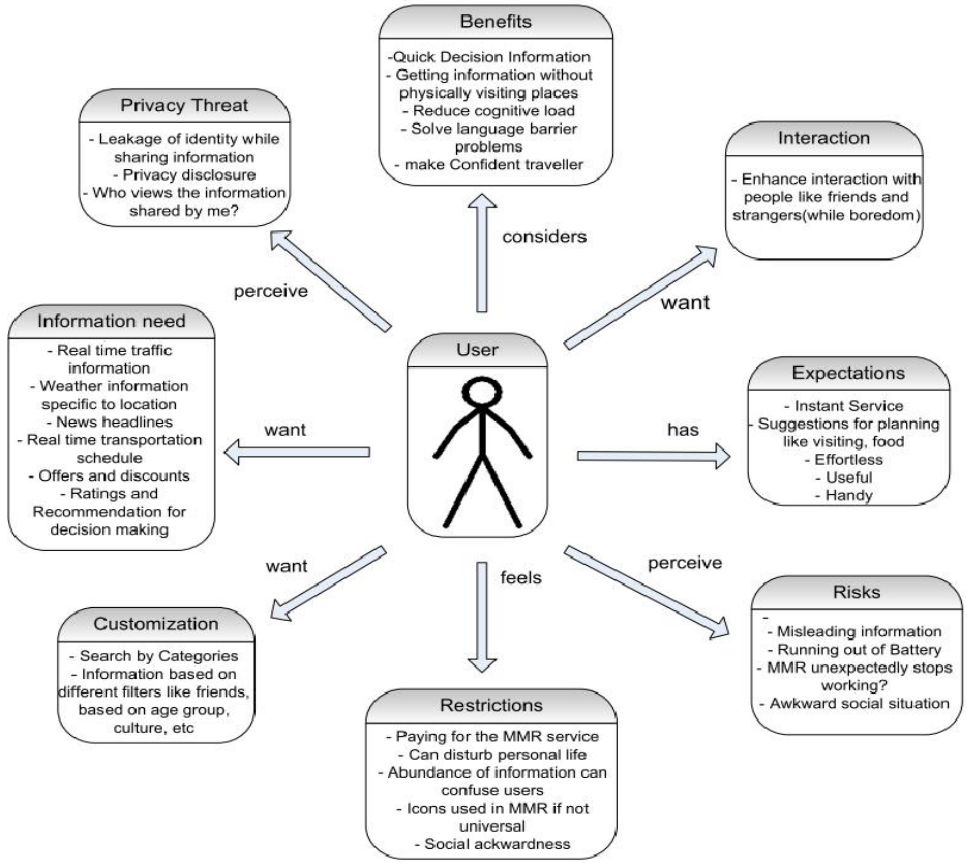

Figure 5.12: Results from Affinity Diagram

5.3.2 Information Needs

Information needs refers to the kind of information any future MMR user will be interested in using. Participants gave varied types of information needs and agreed that the different types of information must be shown in form of information clouds augmented on the physical space like on buildings and streets . These are information needs related to real time traffic, weather specific to a location, newspaper headlines, real time transportation schedule, offer and discounts, rating and recommendations for decision making and information on current and future happening of their surroundings. Majority of participants have agreed that this kind of information supplement their existing knowledge about their current environment and surroundings. Some of the qualitative comments are - *"Many times it happen that I come to know about offers and discounts through my friends and their circle, social media and printed advertisements at my house but really when I need to buy*

anything and I am looking for any such source then all these information sources become invisible (group session 2, female 23)" and *"MMR is handy as it is always with me in my cell phone, I always keep my mobile with me so I can get suggestions and help anytime (group session 4, female 42)".*

5.3.3 Expectations of MMR

Participants have mentioned different kind of expectations from any future MMR application. Majority of participants have agreed on that MMR application must be of instant service, act as a personal event organizer, give trustworthy suggestions for planning like visiting and food; it must be effortless in use, handy and usable. Some of the participants have emphasised the role of icons and symbols used in displaying MR content such as *"Icons must be intuitive and acceptable internationally"* and *"If I am in some critical situation and MMR shows me some weird icons that I cannot deduce then MMR is crap (group session 2, male 28)".* Apart of the above mentioned responses, some less common expectations are - *"MMR must work all over the world (group session 2, male 26)"*, *"MMR must support all different types of content like video and audio (group session 1, male 26)"* and *"MMR can show if a restaurant is already full so that I don't waste my time (group session 3, female 44)".*

5.3.4 Benefits of using MMR

Regarding benefits of using MMR, I have classified the benefits in four categories based on the participants' discussion. Participants have stated benefits of using MMR on *"individual level"*, *"social"*, *"business"* and *"travelling"*.

There is rather much discussion on how MMR can benefit any individual and its lifestyle. Participants have mentioned different answers to this such as MMR helps in quick decision making, participants in one's decision process, reduce cognitive load of a user and one can get information without physically visiting places. One participant mentioned *"If MMR give suggestion like which place is worth watching and which is not. Like good or bad then it is something cool (group session 1, female 24)".* Furthermore, almost all participants agreed that MMR is very useful and make their life easier.

MMR's role in travelling is recognised during the discussion. Some participants mentioned that users' can become confident traveller and they can visit places at their own pace. Several participants have emphasised the role of MMR in solving language barrier. This may be due to the fact that majority of the participants are foreigners living in Finland so they may be associating this particular usefulness of MMR with their own context. Some

participants mentioned *Good for places with language barrier where English is not the primary language of instruction (group session 2, female 26)* and *"This kind of information is really useful like while travelling to places like China and Japan, come on after all how many languages you can learn and especially when it is Chinese. I am clueless (group session 3, female 33)"*

MMR is broadly seen as a social application that enables its users to experience social well being. Majority of the participants have mentioned that they would like to use MMR as social network application like Facebook where they can share information with their own social network. Almost all participants agreed that MMR can help in solving boredom, act as a 24x7 assistant for a user, and make you feel secure and safer. Some participants mentioned *"MMR is handy compared to traditional sources like newspaper and friends (group session 3, female 33)"* and *"We can use MMR when we do not trust people around us (group session 2, male 26)"*

There are some discussions on *How MMR can support business or generate revenues.* Almost all participants have agreed that discounts and offers attract users and information dissemination is very fast in MMR. These two reasons support MMR's role in generating revenues. Some participants mentioned that almost all kind of businesses will be interesting in investing in MMR as it promotes their business directly. One participant mentioned *"Newspaper advertisement is old now and companies/shops are always looking for new channels of advertisement to directly reach their customers (group session 1, male 28)"*

5.3.5 Interaction with MMR

Interaction with MMR refers to the design suggestion that came forward during the focus discussions. Participants have mentioned some very interesting use cases like *"how would they like to use MMR"* and *"what type of interaction should MMR support"*. One participant mentioned that during conferences and social gathering it is very difficult to recall each and everyone with their name, designation and current work so it would be nice to see some kind of information tag representing their name and destination. Others can see this kind of information through MMR so it solves this real life problem which he often faces. Later on this suggestion, almost all participants agreed and expressed their willingness in this interaction case. Furthermore participants mentioned that such use cases increase the overall interaction and make them more competent professionally. Apart of this other design suggestions are - *"Chat with strangers on streets and outside restaurants (group session 2, male 26)"* and *"Introducing some kind of playfulness in MMR such as having a virtual pet (group session 2, female 25)"*. Other less common de-

sign suggestions are mainly related to *How MMR can make its users socially competent and solve boredom?*

5.3.6 Restrictions in MMR adoption

Participants stated different reasons that pose restriction in the adoption of MMR as a daily aide. A handful of participants mentioned that they do not feel the need of using this application in their own country or in the country they have been staying for some time. Paying for MMR is widely recognized as a potential restriction in its adoption.

Analysis of results revealed that participants are willing to pay for MMR only in two situations - 1) charges of using MMR are minimal (participants do not quantify as what is minimal charge). 2) User is in some foreign country. Almost all participants have mentioned that they prefer using MMR in the foreign country because of language barrier and unfamiliarity with a new place. Participants expressed their opinion like *I can use this app and pay for it if I am in a foreign country where I have a language barrier but if I am in my own country then I wonât use this app (group session 2, female 26)*, *"If the amount is not too much then I am ready to pay for it (group session 2, male 26)"*

Furthermore, some of the participants also mentioned that they will be ready to pay for the application for number of other reasons. For example, if the application is useful, provides instant service and required less effort for using it. *"I could pay for it if it is easy to use and handy. I can pay for it if I do not need to type so many buttons and I can get information in seconds. I want instant service (group session 3, female 33)"*.

Few participants expressed that MMR application can affect their personal life by disturbing their peace and making them spent more money by giving them information about available offers and discounts. One participant mentioned that *"It can disturb my life as it takes me to those shops where I would have never shopped due to budget issues (group session 3, female 44)"*

Other than above listed reasons, some participants also revealed their inability to understand the used icons/symbols in MMR content and roaming charges for using internet while present in a foreign country might also restrict them in making use of MMR. Less common reasons stated by participants are *"Cold weather restrict you from using this app (group session 3, female 31)"* and *"Difficult to use for female as they generally have heavy shopping bags in hands (group session 3, female 31)"*

5.3.7 Privacy threats on using MMR

The study revealed that participants are concerned about their privacy in using the MMR application. Majority of the participants are concerned about the privacy issues in regard with sharing of the information. The participants stated that privacy threats such as revealing their personal information namely - sex, age, name, and email and location while using MMR would force them to discontinue using the application. However, it is also found that participants are ready to share with their nicknames and unidentifiable personal information. Other comments related to the privacy risk are *"If my comments are shown like 25 years of female then I don't mind sharing that kind of information but it if MMR shows my exact email and phone number etc then MMR is affecting my privacy (group session 3, female 31)"* and *"Due to privacy risk I want to view only information rather than posting to this app (group session 1, female 24)"*

5.3.8 Risks associated with MMR

The study revealed several potential risks that can be posed by any prospective MMR application. The usage of MMR application suffers from inherent risk of showing stale or incorrect content that can mislead MMR users. Majority of the participants agreed that projection of too much information, unnecessary and misleading content are the biggest hurdles in the route to MMR adoption by mass users.

The analysis of the results showed that participants are concerned about the identity of the people viewing and sharing the information and ratings along with the administrator, responsible for managing and visualizing the shared information on the MMR application. *"Sometimes people buy things recommended by hundred people on Internet but it might happen single person has put all those comments (group session 4, female 42)"*

Large numbers of participants have mentioned that running out of battery and cracking of MMR application in the midst of its usage in critical situation are its other potential risks. Both these risks are common in any mobile phone application in critical situations like business meetings, etc. Participant stated *"This kind of application will consume lot of power and if I am in a foreign country having different language and suddenly MMR stops working then? (group session 1, male 26)"*, *"Pretty worried about the battery running out (group session 1, male 26)"* and *"If I blindly trust this app in foreign country and you don't took any maps or other information but suddenly the app cracks. You trust it too much (group session 2, female 25)"*.

Apart from the above listed risks, many participants have mentioned that usage of MMR also poses risks of behaving socially awkward while on streets and sitting at public places. One participant mentioned *"When I use this app then it appears like I am clicking pictures so public might feel awkward due to my actions (group session 2, male 26)"* Some participants also thought that it would be dangerous to use this application while driving and MMR user can even strike any wall, pillar or building as all time his/her focus in on looking at mobile phone screen.

5.4 Alternative method for Data collection

MMR is considered a futuristic technology and currently only few people use this in their daily life. Users often find it difficult to express their views and opinions on a technology which seems unrealizable at that moment. Furthermore, users themselves do not know what kind of product they would like to have [49]. Due to these reasons, designing a MMR application based on user needs and expectation becomes not only difficult but challenging. Contextual inquiry is a well known method for understanding the users, their needs, expectations and current practices [49]. But practicing contextual inquiry can be challenging when the focus is in future. Contextual inquiry requires observing and enquiring users when they work in order to understand their motivations and actions but as mentioned before MMR is futuristic so people do not use it in practice. Context of use of any product is important in designing interactive product and determining the product's UX. Focus group session is also a useful method for elicitation of user needs but traditional focus group sessions are performed inside the closed office premises so they are considered ineffective in understanding the context of use. Even though different stimulus agents are introduced during focus groups such as pictures, videos and textual scenarios but still they are incompetent in concretising the concepts based on novel technologies like MMR.

To overcome the challenge of designing MMR product based on user needs and understanding the context of use, I developed a method called *Lost Foreigner*. It may help in better understanding the potential users of the MMR when they are present in their own real environment. Furthermore, I consider users' physiological, social and psychological state as crucial in the adoption of any new technology or concept so this new method can possibly elucidate these states. However the validity and authencity of the gathered responses is questionable.

Lost Foreigner has several benefits as it enables any product designer to quickly gather user needs, expectations, opinions and motivation at no

cost at all. Furthermore unlike other user research methods where users are given monetary rewards for participation, *Lost Foreigner* does not require the interviewee to pay anything to the interviewer so it is cost effective in nature.

Unlike focus group sessions, *Lost Foreigner* method is performed in real environment where the user is present and stimulus like edited pictures with textual information are used. It is similar to contextual enquiry in a way as it also involves master-apprentice model of interaction with the test participants. A user act as master and teaches interviewer how the work is done, what is good and bad.

5.4.1 Study Methodology for Lost Foreigner

Lost Foreigner consists of following four phases. First, test moderator takes the picture of the location or building where the test has to be conducted. In the second phase, picture is edited using a drawing tool like Adobe photoshop and textual information tag is added to it. As this method makes use of deception and illusion so to get authentic results, the study must be performed by a foreigner to the place where test is to be conducted. The added textual information must be the native language of the place of study. For example in my study, study is conducted by an Indian living in Finland and textual information is written in Finnish. After adding the textual information, the picture is uploaded to the mobile phone. In the third phase, moderator interacts with the user by asking for help to anyone present in that location for-example, *"what is this place or building and for what it is famous and so on"*. Test moderator will act like a lost foreigner who is first time visitor and new to the place. Fourth phase is deception and illusion where edited picture is shown by the test moderator and people are asked to read the written information as it is not in English. This introduces a positive surprise element to the interviewee who will explain his or her views and motivation for such kind of technology or concept.

Example of *Lost Foreigner*, I photographed the main building of Aalto University located in Otakaari 1, Espoo. The picture is later edited and following information tag is added, *"Lämmintä pullaa ja kahvia edullisesti opiskelijoille"* meaning that *"Cafe inside is serving hot bread and coffee at cheap price for students"* (see Figure 5.13). After this, I open the edited picture in my mobile phone. I asked for help to a student standing nearby like *"Hey, I am an exchange student in Finland and yesterday I came here from India. This is my first time in Finland so could you please help me"*, *"What would you say about his place for a foreigner?"* This helps in starting the conversation and the student (interviewee) will give some information about

that building. After getting his answer, I pretended to picture the building using my mobile phone. I further extended the conversation by saying *"My mobile has a new application which has got the following information about this place but the text is in Finnish so can you read for me?"* This creates a positive surprise effect to that student who will willingly answer more questions about this experience and technology. *Lost Foreigner* is an

Figure 5.13: Edited picture used during Lost Foreigner testing

interesting way to understand the people's viewpoint on the surroundings and their readiness to share different kinds of information related to it for example, the information that they know of, their own experiences, suggestion, and opinions and so on. The role of *Lost Foreigner* in MMR domain is interesting as it accurately explains the MMR concept to its potential users. It creates an interesting surprise effect for the participants due to acting like a foreigner so it also stops people from further interviewing and express their real opinions.

Conducting user studies can be challenging if performed in an ad-hoc setup meaning participants are not hired but people in any busy location are interrupted and asked for participation. It is found that it is hard to

stop people and ask them to think on the matter at hand but *Lost Foreigner* solves these problems due to the introduction of surprise effect during the interview.

5.4.2 Participants of Lost Foreigner

A total of 12 tests are performed using this method in Helsinki area. All tests are performed between May-June, 2011. It took 15 minutes on average for each test. Six interviewees are young technical university students at Aalto University Campus (4 males, 2 females). Four interviews are middle-aged interviewees near the shopping complex located in Ruoholahti, Helsinki (1 male, 3 females). Other two interviews are performed with old aged interviewees outside kamppi shopping mall, Helsinki (2 females). Total of 5 males and 7 female participants are interviewed.

5.4.3 Apparatus and Study Setup

In all the experiments, I used Nokia N900 mobile phone, Adobe photoshop for editing pictures and entering text and plain paper, pencil for writing down the important observation and participants' comments.

The study is conducted at three different places having three different scenarios. First scenario is created outside the main building of Aalto University located at Otakaari 1, Espoo. MR content in form of discount and offers related to tea and snacks is added. Second scenario is created outside a shopping complex located in Ruoholahti, Helsinki. MR content in form of weather forecast, outside temperature, discounts and offers related to groceries is added. Third study took place at outside of kamppi shopping mall, Helsinki. MR content displaying current news fetched from yle.fi, directions to important events happening in the city, discounts and offers are shown to the participants.

During each interview, I asked four questions that are intentionally kept same for every test participant. These interview questions are asked in chronological order namely -

1. *"I have one application running on my mobile phone but it shows text which is not in English, can you read this?"* Kindly help me in translating this text.

2. After the participant has read the Finnish text then I said *"see technology has advanced so much this application is my best friend as where*

ever I go it shows me all information like a tourist guide but it sometimes display content in local language of the country where I am using it"

3. *"Do you like this application?"* It works everywhere it shows me weather forecast, temperature, latest happening and headlines, discounts and offers and everything happening in your surroundings. What else someone can expect from it?

4. *"What is your opinion about such applications?"*

5.4.4 Results from Lost Foreigner

Lost foreigner method is performed with the main intension to understand users' behaviour when any user interacts with any potential MMR application for the first time. Mostly gathered results are based on my own memory as recording is not performed while interviewing users. Audio recording any conversation without informing users is considered unethical and an illegal practice. After performing each test, I quickly go to any near by coffee shop and note important observations on paper. Majority of the participants experienced an element of surprise when I showed the edited picture. However almost all technical students are exception to this kind of behavior. The possible reason could be that they play around with Google street view and other location specific applications daily so for them this kind of application is not new so they did not express anything due to lack of surprise element. Due to the limited time and less focus, I am not able to draw any design implication for such experiments. So no changes are made in the designed prototypes and proofs of concept.

Chapter 6

Evaluating User Experience of the Prototypes

This chapter outlines the last empirical part of the thesis performed by using three different UX evaluation methods (see Section 3.4). I evaluated UX of MMR prototypes and proofs of concept developed by me using UCD methodology. These prototypes and proofs of concept are based on the results of different phases of the UCD (see Chapter 5). Section 6.1 presents the goals of the evaluation. Section 6.2 and 6.3 briefly presents four prototypes and five other proofs of concept on MMR that are used for evaluating UX. Section 6.3 describes the study methodology covering apparatus used, participants' profile and study procedure. The results from theis UX evaluation study is presented in Section 6.5. Finally in the Section 6.6, overall UX evaluation study is summarized.

6.1 Goals of the Evaluation

UX evaluation helps in determining users' expectations before using the product and users' perception after interacting with the product (see Section 3.4). The main goals behind this phase are:

- Goal 1: To evaluate UX of the MMR prototypes and proofs of concept by applying different methods for evaluating its hedonic and pragmatic aspects in the specified technology context.
- Goal 2: Determine those elements that affect users' expectations and perceptions in regard to early demonstrators of MMR.

The above defined goals relates to the research question (see Section 1.3) behind this thesis i.e. to find suitable methods for evaluating UX of de-

signed MMR prototypes and proofs of concept. The methods chosen by me for UX evaluation can potentially help in collecting quantitative as well as qualitative user feedback and opinions on the created prototypes and proofs of concept. Furthermore, the goals behind this empirical evaluation study answers user needs and expectations from MMR which is also one major part of the research questions (see Section 1.3).

Based on the empirical results of the UCD methodology, I created four semi-functional MMR Prototypes and five non-functional prototypes in form of proofs of concept, describing scenarios that could be possible with MMR technology. I used different techniques for visualizing prototypes and proofs of concept. The used techniques and software tools are discussed in Section 6.2 and Section 6.3

6.2 Semi-functional MMR Prototypes

I created four semi functional prototypes based on the results of empirical UCD (see Section 5.3). First two prototypes are implemented using Google Map API's[1] and running on Samsung Nexus S[2] and Nokia N900[3] browsers, third prototype in using Photosynth service[4] on a laptop and fourth prototype in implemented using Nokia Flowella[5], a rapid prototyping tool on Nokia N900 mobile phone.

The created prototypes differ and complement each other at the same time. For example, first two prototypes are similar in a way that they present MR content in Google street view but both these prototypes differ in type of interaction they support. At the time of deciding MMR prototypes, I decided to focus on different factors such as type of interaction, type of MR content and mode of MMR application use that can be either inside the building or outside locations. Similarly third prototype presents panoramic view of different locations like inside location, outside of a building and displaying MR content. Fourth prototype gave an overall view of MMR in form of a semi-functional MMR N900 application.

[1]Google Maps API, http://code.google.com/apis/maps/index.html Last visited 15 May 2011, 7.44 am

[2]Nexus S Android Phone http://www.google.com/nexus/ Last Visited 02 June 2011, 11.41 am

[3]Nokia N900, http://www.nokian900.com/ Last visited on 28 May 2011, 09.21 am

[4]Photosynth, http://photosynth.net/about.aspx Last visited on 5 May 2011, 9.04 pm

[5]Flowella Tool http://www.developer.nokia.com/Resources/Flowella Last visited on 14 March 2011, 14.21 pm

6.2.1 MR Street View

The first prototype is based on the idea of displaying MR content in a street view of any particular location. The concept of displaying MR content in form of different icons like football representing sport stadium, fork and knife describing a place to eat and a wine glass referring to bar is considered intuitive by the test participants of the focus group discussion because scenario similar to this idea is shown during user research. Google and Bing maps do not provide the facility of tagging any location in street view due to which creating such kind of experience is not only difficult but impossible too. I decided to perform this difficult orchestration by using existing Google Maps API's and mark-up languages like HTML[6] and XML[7]. My aim is to give users an immersive view on having MR content in form of digital icons tagged anywhere on a street view of a particular location. The orchestration is performed in form of scripts that are hosted on a remote Apache server[8] running on a laptop placed inside the same room where UX evaluation is carried out. Nokia N900 and Samsung Nexus S browsers are used for displayed the hosted content. It is found during two different pilot tests that navigating of the hosted content on Nokia N900 phone is sometimes difficult for users. Both pilot test users face problems in quickly zooming in/out and navigating the displayed content. However, pilot users did not face any such restriction while using Samsung Nexus S so I finally, decided to use Samsung Nexus S for the UX evaluation.

I fetched the Google street view of Otaniemi, Finland by using longitude and latitude co-ordinates of Otaniemi in the prototype scripts.

Prototype enables test participants to pick and tag any desired location by using three different icons. All icons contain a tooltip containing a textual description like vegetarian restaurant, dinner and sports stadium.

At the time of UX evaluation, participant is given a device having MR Street view prototype running on its browser (see Figure 6.1 and Figure 6.2). First of all, participant is introduced with the idea of having such digital icons attached to any particular street, place or location of their choice. Furthermore, it is explained that participants can save the location tagging for their own reference in future or share with their friends. After the introduction, participant is asked to navigate in the displaced map and arrange those icons to their place of interest. Participant is instructed to first zoom into the maximum level of the map and then switch to the street view where they can view already placed icons or edit the current location of the icons to tag

[6]Hypertext Markup Language, http://www.w3schools.com/html/default.asp

[7]Extensible Markup Language, www.w3schools.com/xml

[8]Apache Tomcat http://tomcat.apache.org/ 17 May 2011, 8.14 pm

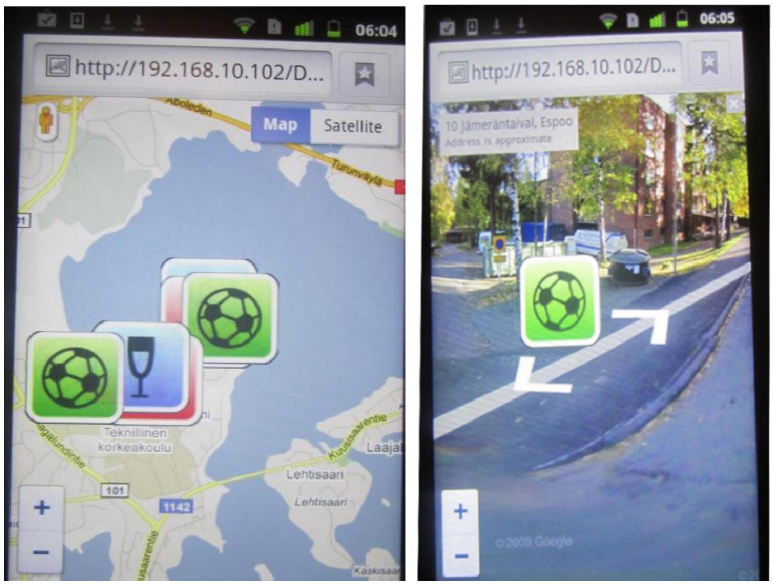

Figure 6.1: Map and street view displaying MR content in form of icons

the place of their own choice. On average it took 5 minutes for a participant to test this functionality.

6.2.2 Toggle Street View

The first prototype discussed above, enables test participant to view both map and street level view of any location at the same time but user is required to zoom in-out inorder to switch between map view and street view. However the second prototype provide a toggle button so that the test participant can switch between the map view and street view. During user research, it is found that users often face problem in quickly viewing map view and street view of one location due to zoom in and zoom out touch interactions.

The second prototype is also hosted on Samsung Nexus mobile using the similar orchestration that I performed in the first prototype.

In the beginning of the test, participant is given a mobile phone having second prototype running on its browser (see Figure 6.3). In this case, no introduction for required unlike the previous prototype as participant is already familiar with the idea of displaying MR content in map and street view. However participant is informed that *" Toggle Street View"* button is provided in the top left corner of the application so they can switch between map view and street view any time during the interaction with this prototype. On average it took 6 minutes for a participant to test this functionality.

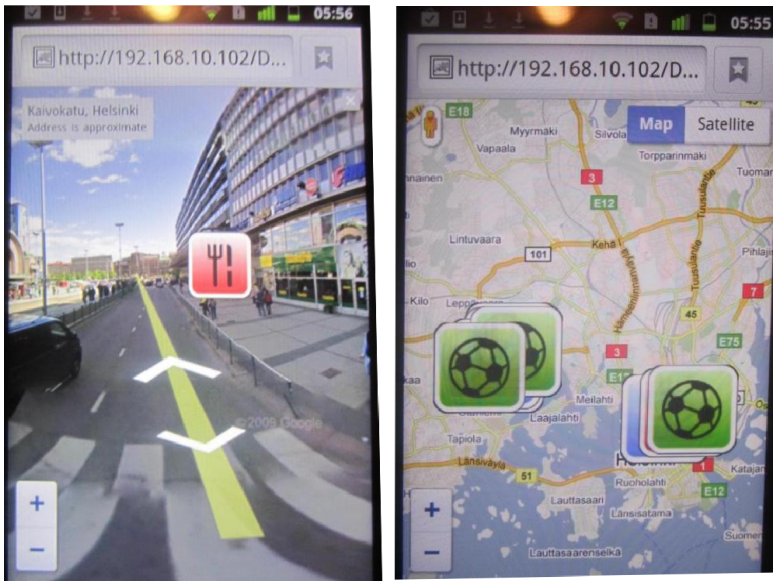

Figure 6.2: Street and map view of some other places displaying MR content

6.2.3 MR Panorama View

Panorama refers to an unbroken and wide view of any place or location. Third prototype is based on the concept of viewing inside panoramic view of any building. The idea behind this prototype is to enable MMR users to view a 360 panoramic view of a particular location or place using their MMR application. These panoramic views contain digital information augmented in form of information tags (see Figure 6.4).

Panoramic views are created using Photosynth tool developed by Microsoft research. I downloaded this tool in an iPod touch as currently this tool is only available for Apple devices. Using this tool, pictures are clicked at a particular place and later those clicked pictures are stitched using Photosynth tool to create a panoramic view. I created four different 360 panoramic views at Department of Computer Science and Engineering, Konemiehentie 2 Espoo, Finland. First panorama is created outside the main door of the department, second near the cafeteria (see Figure 6.4), and third at the backyard of the building and fourth is created inside a big playroom (see Figure 6.5). A total of 44, 36, 52 and 31 images are clicked in each of these panoramas which are later stitched to create four 360 panoramas. The number of images, clicked for creating panorama are random and there is no logic

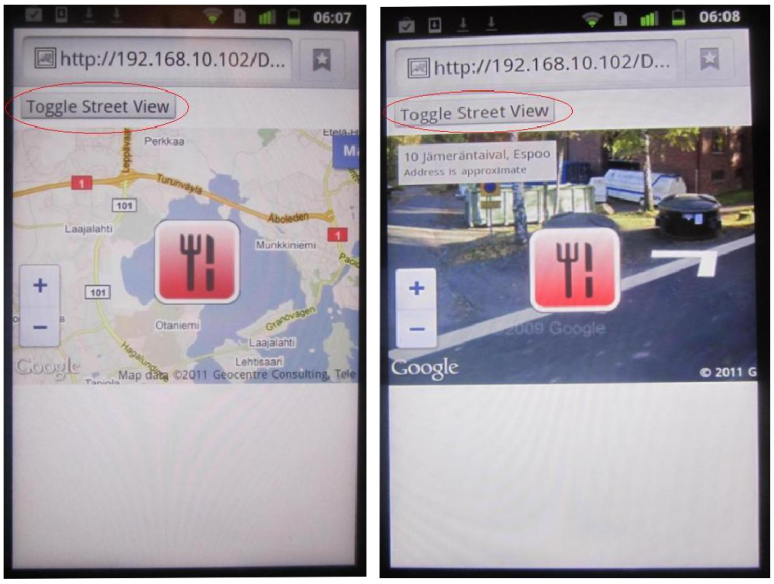

Figure 6.3: MR Toggle street view versus Maps view

behind having different numbers. I paid emphasis on creating a whole 360 panorama so depending on the location and surroundings; the number of images clicked varies.

During the pilot test, moving between four panorama scenarios is taking huge time on mobile phone screen so I decided to use laptop and TV for showing this prototype.

In the beginning of the test, participant is introduced with the first panorama scenario (see Figure 6.4) having MR content displaying *"Hot coffee served here"* on the cafeteria view. The 360 panoramic view of the cafeteria is shown having different information tags displayed. Similar to first panorama scenarios, other scenarios are shown to the participants. It took 6 minutes on average to show all four panoramic scenarios.

6.2.4 MMR Application on N900

The fourth prototype is based on the idea of showing an overview of a functional MMR application running on a mobile phone (see Figure 6.6). I created a semi-functional prototype called *" Aalto MMR"* that displays MR content on maps and other associated functionalities. This prototype is created using Flowella. I created 800x 480 pixels images of different screen mock-ups for

Figure 6.4: Panoramic view of cafeteria displaying MR content

Aalto MMR using Adobe Photoshop CS5 tool[9]. A total of 16 screen mock-ups are constructed and each of them complies with Nokia N900 Hildon UI guidelines [10]. After creating different screen mock-ups, I used Flowella tool and imported all screen mock-ups. Later an interaction sequence to the created screen mock-ups is defined and created prototype is exported as a Flash Lite application[11]. This exported application is open and executed on my test N900 mobile phone. Aalto MMR contains different features such as search content, tag information; filter information based on certain pre defined access levels and group view containing information on users' profile, friends and favorite places (see Figure 6.7). At the time of experiment, participant is given N900 mobile phone having Aalto MMR prototype running. Participant is instructed to think aloud while navigating all different views of Aalto MMR and interrupt me in case of difficultly or if any information is not clear. Furthermore, every participant is enquired on the clarity of displayed icons, symbols and written text. On average it took 7 minutes for a participant to test this prototype.

[9]Adobe Photoshop CS5, http://www.adobe.com/products/photoshop.html Last visited 17 March 2011, 6.12 PM

[10]Hildon UI Guidelines wiki.maemo.org/Hildon Last visited 24 Feb 2011, 8.32 AM

[11]Flash Lite, http://www.adobe.com/devnet/devices/flashlite.html Last visited 24 Feb 2011, 11.28 AM

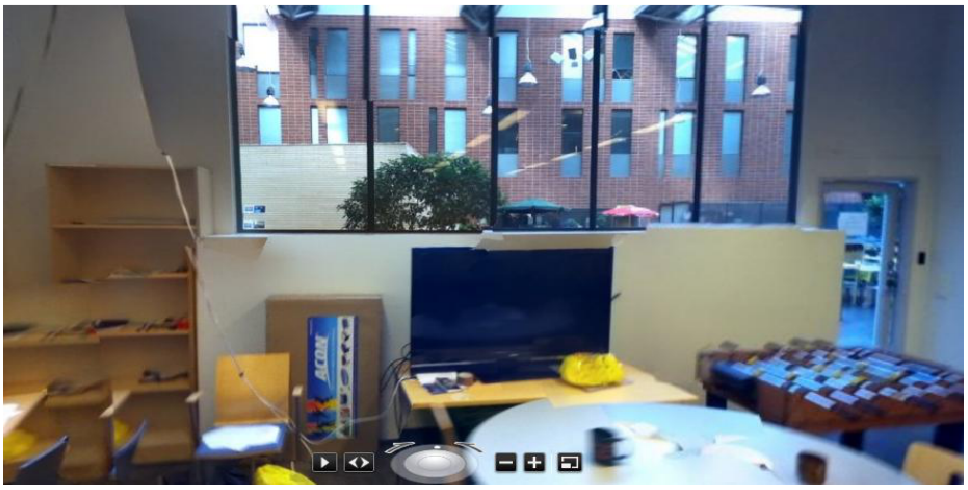

Figure 6.5: Panoramic view of playroom

6.3 Non-functional MMR Prototypes - Proof of Concept

As the result of empirical UCD, I prepared five different proofs of concept (see Section 5.3). First three proofs of concept are visualized by creating short video animations having annotated text in form of information tags. Other two proofs of concept are visualized using sketching, drawing and creating storyboard through power point slides. Participants are shown videos and power point slides in one by one sequence using a laptop connected with TV. Participants are asked to think aloud on the shown information and they can ask anytime if something is unclear or needs further explanation.

I chosen five proofs of concept as these further concretize the MMR concept and its possible uses in the mind of the users. Furthermore, these proofs of concept are produced from the focus group discussions so it is important to evaluate how much experience these concept can generate from users' point of view. The presented proofs of concept differ from above mentioned prototypes in the level of implementation and details for example prototypes are semi functional while proofs of concept are merely illustrations. The reason for having five proofs of concept is that I wanted to test different innovative design idea which I came across during user studies. I tried to fit those different design ideas into five proofs of concept that are discussed below.

Figure 6.6: Overview of Aalto MMR running on N900 mobile phone

6.3.1 MR Outdoor Navigation

The first proof of concept is based on presenting MR view of any outside surroundings by displaying information tags containing weather forecast (see Figure 6.9), real time traffic for any destination, outside temperature (see Figure 6.8), current headlines of a newspaper and displaying name of any building (see Figure 6.10). A short video of 1.12 minutes is shown. During the user research, I found that users are very much interesting in knowing about the facts that I shown in the video. Several users have mentioned that currently they face many problems in accessing information related to their surrounding like - *" Helsinki Sonamat is so thick who has time to read each and everything, I would love if someone can put important headlines in front of me (female 31, focus group 3)"* ,*" Everyday in the morning, I need to search for weather forecast before leaving for office, Can MMR show me this kind of information as a information cloud? (female 33, focus group 3)"* and *" Real time traffic information is given by radio stations but I often do not find traffic related information when I am really in need for it (male 23, focus group 2)"*

Based on these facts, I designed this prototype, displaying MR content in outside surroundings. This kind of information supplements the users existing knowledge and information space. Furthermore, it is a one stop source of information for MMR users.

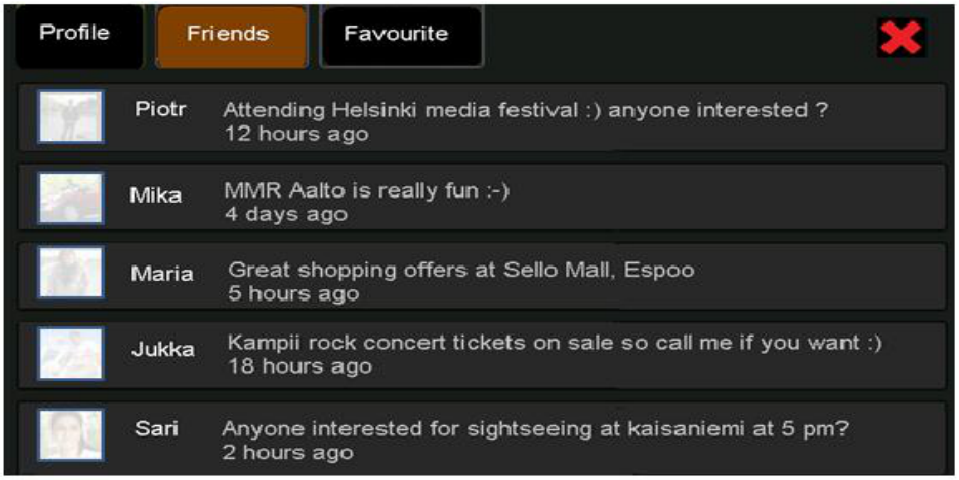

Figure 6.7: Overview of Aalto MMR running on N900 mobile phone

6.3.2 MMR bridges Language Barrier

In the second proof of concept, participant is introduced to an idea as *" How MMR can potentially solve the language barrier problem"* using a short video of 23 seconds of duration. The video contains different sight scenes in china particularly reflecting market and street view having large hoardings written in Chinese language. The video displayed the translated English content tagged to those hoardings in form of information tags (see Figure 6.11 and 6.12). My goal is to give users a basic understanding as how they can use future MMR applications in viewing displayed content in a language that they can fairly read and understand.

6.3.3 MR Indoor Navigation

Third proof of concept is based on the idea of *" making users aware about their surroundings inside any building by displaying MR information tags"* using a short video of 49 seconds duration (see Figure 6.13 and 6.14). The video contains different scenes from inside view of a building. Video displays different information tags that make any user aware about important happenings taking place at his or her location. Examples of the shown content are namely - *" summer course starting next week so register yourself at second floor room number A221"*, *" course on technical writing going on at T1 room"*, *" cloud computing group discussion at progress"* and so on. These kinds of information can potentially be useful for a MMR user as it supplements users' existing knowledge about its physical surroundings.

Figure 6.8: Information tag containing atmospheric temperature and traffic information

Furthermore it eases users' cognitive load. Through this proof of concept, I aimed at providing potential MMR users an understanding on how MMR can enhance users' existing knowledge about the current and future happening of a particular place or location.

6.3.4 Playfulness in MMR

The fourth proof of concept is based on the idea of having playfulness in MMR application. Concept of virtual pet is introduced in order to motivate MMR users so that they can share information and make use of MMR as a utility in their daily life. Powerpoint presentation containing four slides is used to describe the whole concept while I read the textual description of this proof of concept written on a piece of paper for each participant during experiment. Virtual pet can be described as a concept where MMR users either select one of the virtual pets shown by the MMR device or they can create their own virtual pet. Based on their activity on MMR application referring to the amount of time spent, information shared and service used, participants can earn points which can be used for buying food for their pets. In order to enhance the sporting experience of the MMR users, concept of earning weapons for virtual pets is introduced (see Figure 6.15). MMR users can challenge their fellow friends who also own such virtual pets. The earned pointed as also be used for buying weapons for their pets. MMR users can also interact with their virtual pet using MMR application (see Figure 6.16). The concept of virtual pet supports social experience as MMR users have 24

Figure 6.9: Information tag displaying weather forecast

x 7 virtual pet that is present anywhere and anytime.

6.3.5 MMR Interaction

Fifth proof of concept is based on the idea of making users aware on how they can interact with different physical objects using MMR through information tags. Powerpoint presentation containing three slides is used to describe the whole concept while I read the textual description of this proof of concept written on a piece of paper for each participant during experiment.

First slide presents a scenario where people can be tagged with information tags containing their name and designation (see Figure 6.17). These tags are namely - *" Aino, Student at Aalto University"*, *" Juha, Scientist at Aalto University"* and *" Jarno, Manager at Nordea"*. This tagged information can be viewed through a MMR application. At conferences and other social gathering, it often happens that people find it difficult to find others who meet their taste and interest. Furthermore, people experience cognitive load as they have to remember others with their names and designation. Keeping these two facts in mind, I designed this scenario as it helps MMR users in tackling with the above listed problems. Second slide presents a scenario where two MMR users i.e. *" Aino and Juha"* are sitting inside a restaurant and chatting with someone who is standing outside that restaurant (see Figure 6.18). MMR facilitates such interactions when a MMR user can interact with other MMR users who are unknown and there do not exist any previous relationship. During the user research phase, several interesting facts related to interaction in social settings are found. For example, some test

Figure 6.10: Information tag displaying newspaper headlines and building names

participants mentioned that they are interested in taking with even strangers when they feel boredom and alone but they face difficulties in approaching others for conversations. Furthermore, some participants mentioned that it would be nice if through MMR application they can create information tag on their own head displaying *" Hey I am feeling bore, anyone here for giving me company?"* This will help them in notifying other MMR users about their wish and hence they can initiate conversation.

Apart from this, some participants mentioned that they always want to know information such as *" What kind of food is served (female 42, focus group 4)"*, *" How is environment inside the restaurant (male 26, focus group 1)"* and *" What is the usual service time of this restaurant without going inside (male 28, focus group 2)"*. Some participants mentioned it would be nice if MMR application provides some kind of chat functionality where someone standing outside a restaurant can chat with anyone inside and get all the required information.

Keeping the above mentioned facts in mind, I designed this scenario where anyone sitting inside a restaurant can chat with someone on the street using MMR application. Third slide presents a scenario where MMR users can tag different ratings to physical places and objects like restaurants, parks, and cinema (see Figure 6.19). Users can share their ratings with their friends who are also using MMR application. In the scenario, *" a Mac Donald restaurant is given two stars"*, *" Opera is given four stars"* and *" Memphis restaurant is tagged with five stars"*. During the user study, it is found that participants like to see rating and recommendations for places they are or will be visiting.

Figure 6.11: A large Chinese hoarding containing translated English content in form of information tags

I created this scenario keeping in this mind users' expectations and needs from MMR application.

6.4 Study Methodology

In this section, the overall study methodology of the UX evaluation is explained by first describing appratus, participant profile, study procedure and then its implementation. The study procedure is tested using two pilot tests in-order to locate technical problems if any in the study methodology. Each pilot test last for 50 minutes. The results from the pilot test are not recorded or included in the UX evaluation results. During the pilot test, several crucial things are noticed that could possibly affect the study results hence appropriate changes are made in order to avoid such instances. One major finding from the pilot test is related to the understandability of the different terms such as the type of scale used, dimensions, adjectives and facial patterns used in different UX evaluation methods. It is found that the pilot users faced problem in understanding them so training on different terms is introduced. Training is essential in order to ensure that participants understand what is meant with each description, adjective and scale.

Figure 6.12: Chinese city Shanghai Street view having information tag displaying discount/offers

6.4.1 Apparatus

All tests took place in June 2011 at Aalto School of Science, Aalto University, Finland. I used one Nokia N900, one Samsung Nexus S mobile phones, one laptop and a 60 inch LCD Sony Bravia TV 1080 HD in calm and laboratory kind of environment. White empty pages, pencils and ball pen are used by participants to enter their responses. However I used these stationary items in explaining different terms and examples to the participants.

6.4.2 Test Participants

I recruited 10 test participants (9 male, 1 females) for participating in the study based on evaluating UX by using a combination of SUXES, Emocard and AttrakDiff methods. UX evaluation study is performed, one participant at a time. One test session took 1 hour and 15 minutes on average. All participants are master level students at Aalto University. All are having IT background and they can fairly well do programming. Nationality wise their representation is Indian, Chinese and Bangladeshi respectively.They are aged 22 to 28 (Mean = 24.4 years, SD = 2.01). All participants received two university lunch coupons as compensation for their time.

Figure 6.13: Information tag displaying information on summer courses at University

6.4.3 Study Procedure

Triangulation research principle is used in the UX evaluation study meaning three different UX methods are combined as one experiment. However, questionnaire as such are not modified but they are just used in the same study to complement each other. If the original questionnaires are changed then their is a risk of loosing the validity of the tested methods so keeping this in mind, I integrated the original methods. There are three main reasons for supporting my approach namely -

1. SUXES and AttrakDiff questionnaire have many similarities and overlapping statements hence performing SUXES and AttrakDiff for every prototype and proof of concept is not feasible keeping in mind thesis time period. The original AttrakDiff questionnaire contains 28 different bipolar adjective statements so answering 28 questions for each prototype and proof of concept means too much work for the participants. A shorter test is required because large number of prototype and proofs of concept each participant has to rate. In course of this event, I integrated AttrakDiff questionnaire with SUXES and Emocard.

2. All three methods have different area of specialization for example SUXES helps in capturing subjective metrics on user expectations and use experiences, Emocard specializes in capturing emotional response in verbal and nonverbal form and AttrakDiff helps in evaluating the pragmatic and hedonic qualities of UX for any product.

Figure 6.14: An information tag containing information on the surroundings

3. All three methods are not valid for testing all kind of prototypes and proofs of concept meaning different methods are valid for different prototypes and proofs of concept. For example, Emocard can be used both for prototypes and proofs of concept as it captures the emotional response of the users. AttrakDiff can be used only for developed prototypes as it can be difficult for users to evaluate proofs of concept based on this questionnaire as AttrakDiff questionnaire works well with those concept that are already implemented and realized in practice. SUXES can be used for both as it a subjective metrics for evaluating users expectations and experiences.

After keeping above reasons in mind, I developed the study procedure consisted of nine phases (see Figure 6.20). The phases are explained below -

1. **First phase:** Participant is introduced with the study procedure, different phases of UX evaluation and ethics related information. After having introduction, participant is asked to fill the study agreement form.

2. **Second phase:** Participant is asked to answer background SUXES questionnaire by using paper printed forms (see Appendix B.1).

3. **Third phase:** Participants is introduced with the MMR concept. Powerpoint slides containing pictures, scenarios, storyboard and videos are used for this introduction. This training material is same that is used in the empirical phase of the UCD (see Section 5.2.2).

Figure 6.15: Overview of three different virtual pets, their weapons and food is shown

4. **Fourth phase:** Participant is asked to answer SUXES expectation questionnaire by using paper printed forms (see Appendix B.2). Participant is instructed to answer questionnaire based on the introduction on MMR given in phase 3. Before answering the questionnaire, participants are explained different adjectives used in SUXES questionnaire in order to ensure that they choose correct values while answering. After answering questionnaire, participant is interviewed for 2-3 minutes in order to gain their qualitative feedback on the shown MMR introduction. The interview is fully structured and it contains following set of questions -

   (a) How do you choose a particular scale while answering different questions of this questionnaire?

   (b) What do you like in this technology/concept? What do you appreciate?

   (c) What do you dislike in this technology/concept? If yes then why?

   (d) What would you like to improve and see more?

5. **Fifth phase:** participant is asked to answer AttrakDiff questionnaire (see Appendix B.4). Participant is instructed to evaluate the questionnaire based on expectations from MMR. Before answering AttackDiff, I explained all the adjectives used in the AttrakDiff questionnaire so that participant clearly understood the description of every used adjective. Participant is introduced with AttrakDiff questionnaire by giving

Figure 6.16: Virtual dog is displayed on the corner of a street

a demo using two sample questions from AttrakDiff. Participant is asked to rate both the sample questions namely "my workplace is dull - captivating" and "my current mobile phone is human - technical". This kind of training is important so as to make participants comfortable and easy during the test.

6. **Sixth phase:** All four MMR prototypes are shown to the participant in one by one sequence. Participant is instructed to test and play with its functionalities. It took 4-7 minutes on average to test one prototype. After testing, participant is directed to Emocard for evaluating emotional response on the first shown prototype. Later participant is interviewed in order to gain insight on their overall experience with the shown prototype. The interview is highly structured and contains four below questions that are asked every time when a participant answers Emocard. This whole process is repeated for all shown prototypes.

   (a) Why do you choose this picture/scale as an answer for this prototype?

   (b) What do you like in this prototype? What do you appreciate?

   (c) What do you dislike in this prototype? If yes then why?

   (d) What would you like to improve and see more?

7. **Seventh phase:** SUXES experience questionnaire (see Appendix B.3) and AttrakDiff questionnaire (see Appendix B.4) is filled by the par-

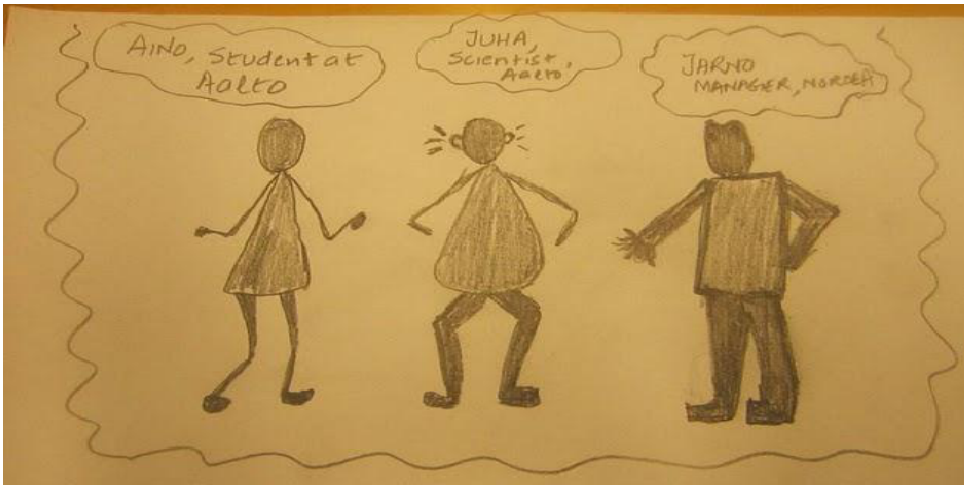

Figure 6.17: People tagged with information tags displaying their names and titles

ticipant. Participant is instructed to evaluate both these questionnaire based on their experience with four different prototypes.

8. **Eighth phase:** Five different proofs of concept are shown to the participant in one by one sequence. After showing first proof of concept, participant is directed to Emocard for evaluating emotional response on the shown proof of concept. Later participant is interviewed in order to gain insight on their overall experience with the shown proof of concept. This whole process is repeated for all shown proofs of concept. Interview is fully structured and it contains following questions

   (a) Why do you choose this picture as an answer for this proof of concept?

   (b) What do you like in this proof of concept? What do you appreciate?

   (c) What do you dislike in this proof of concept and why?

   (d) What would you like to improve and see more?

9. **Final phase:** Participant is asked to answer AttrakDiff questionnaire (see Appendix B.4) and SUXES opinion interview. Participant is instructed to evaluate questionnaire and interview based on their experience with overall MMR prototypes and proofs of concept. SUXES opinion interview is structured and it is performed in order to gain insight on their overall experience with different MMR prototypes and proofs of concept. The interview contains following questions -

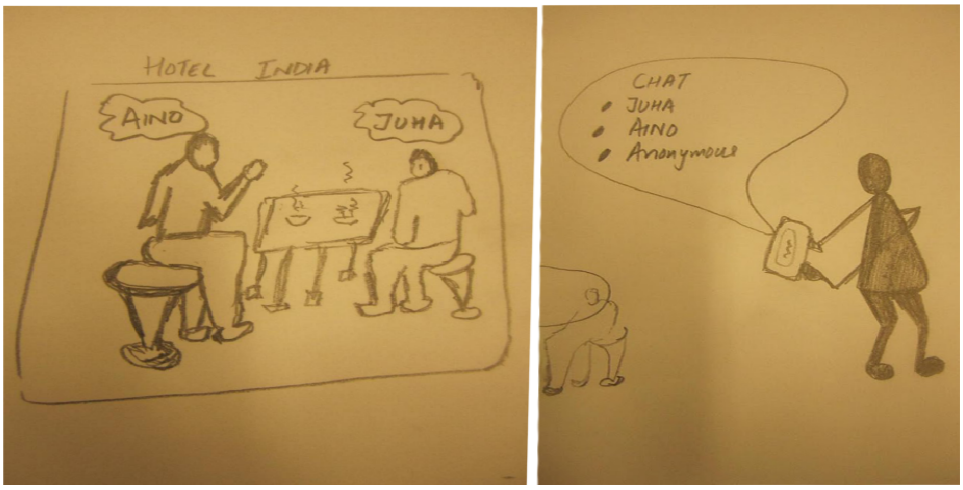

Figure 6.18: MMR users sitting in a restaurant and chatting with a stranger on street

(a) What is your overall response to MMR technology after testing MMR prototypes and proof of concept

(b) What do you like in the shown prototype/proof of concept?

(c) What you dislike in the shown prototype/proof of concept and why?

(d) What you want to improve and/or like to see more in MMR?

The study is implemented by making use of various different aids such as questionnaire printed on papers for taking user responses while performing SUXES, Emocard and AttrakDiff. Initially I decided to keep web wizard for getting user responses on different questionnaire but later I changed the plan and instead used traditional paper surveys. There is a risk that if due to any misfortune user data is lost then I cannot complete this thesis on time. In order to avoid this possible risk, I decided to keep paper survey. The sequence in which MMR prototypes and proofs of concept are shown is randomized. However, all participants are first shown prototypes and then proofs of concept. This is essential because prototypes are semi functional so they nicely concretize the concept of MMR in comparison to proof of concept. The randomization process is as follows - half participants first tested prototype one while other half evaluated prototype two, prototype three and four are also evaluated in similar randomized fashion. After evaluating prototypes, participants tested proofs of concept again in random order. This randomization is essential to control the participants fatigue, accelerated learning and limited session duration [6]

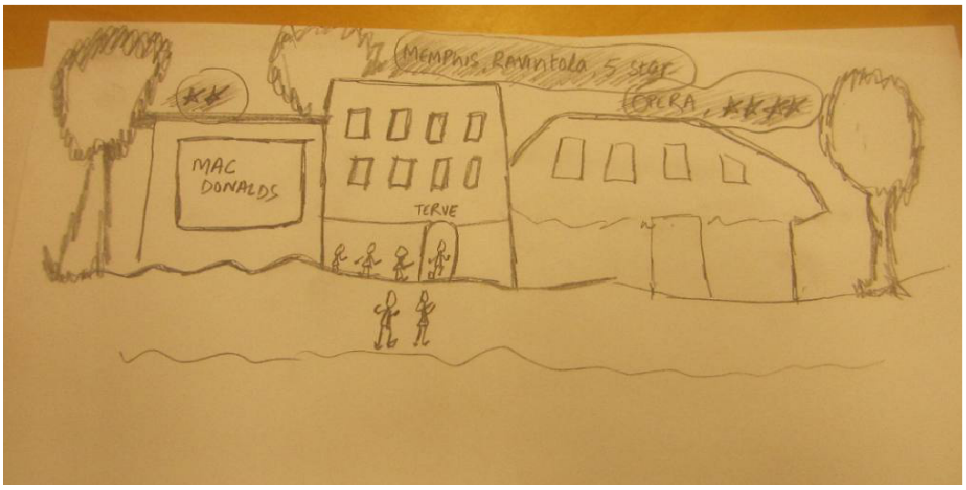

Figure 6.19: Buildings displaying ratings in form of information tags

6.5 Results from UX evaluation

In this section, results of the UX evaluation study are presented. In section 6.5.1, background of the test participants is presented. During the UX evaluation study, both qualitative and quantitative data are collected and analysis of this data is performed at three levels. First, the prototype and proofs of concept specific evaluations are described by presenting Emocard based quantitative results and reasoning based on qualitative data (see Section 6.5.2). Second, the analysis of evaluations about different types of prototypes and proofs of concepts. This is presented by comparing the results of AttrakDiff 2 and 3 questionnaires (see Section 6.5.3). Third, the analysis of expectation versus perceptions or actual UX. This is presented by first comparing the data received from the expectation and perception SUXES questionnaire. This is later complement with the results of comparison between AttrakDiff 1 versus AttrackDiff 2 and 3 (see Section 6.5.3).

6.5.1 Participants Background

In the beginning of the UX evaluation study, all 10 participants filled the background questionnaire to judge their technical orientation and background (see Figure 6.21). It is found that majority of the participants use internet on mobile phone daily and use of social networking sites and VoIP services on mobile phones are popular. Installing of mobile applications, use of location based reminder system and use of map service on mobile phone are found less common among the participants.

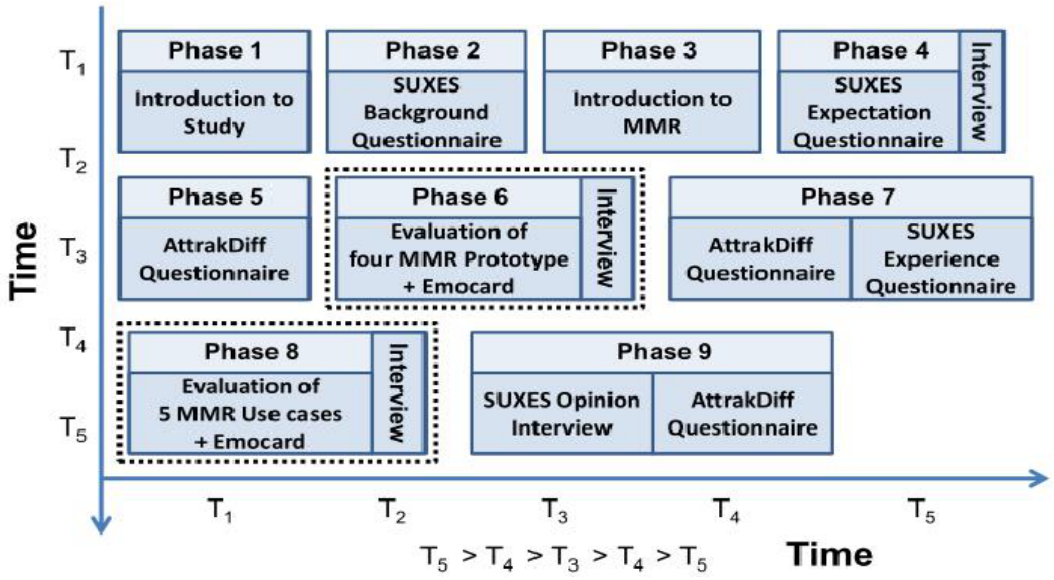

Figure 6.20: Overview of study process

6.5.2 Evaluation Specific to Prototypes and Proof of Concept

This section presents the results from the prototype and proof of concept specific evaluation through the analysis of quantitative responses for Emocard and qualitative data received from the interviews. This kind of evaluation basically answers two broad questions.

1. What did the users like of the different prototypes and proof of concept?
2. What are the UX of each prototype and proof of concept?

Emotional Response to Prototypes and Proof of Concept

All four MMR prototypes are appreciated by the participants and are regarded as *"Pleasant, easy to use and nice"* (see Figure 6.22). However, proof of concept are also appreciated but with an exception. Among all the nine shown prototypes and proofs of concept, *"Playfulness"* is recognised as *'unwanted"* and it received different opinions of the participants based on their likes and dislikes. *"Language barrier"* is regarded as an asset for any future MMR application. It is highly appreciated and received maximum positive responses compared to all other prototypes and proofs of concepts.

During the study it is found that almost half of the participants faced difficulty while answering the Emocard. For example, some of the participants repeatedly asked like *"please tell me which one is more positive and which*

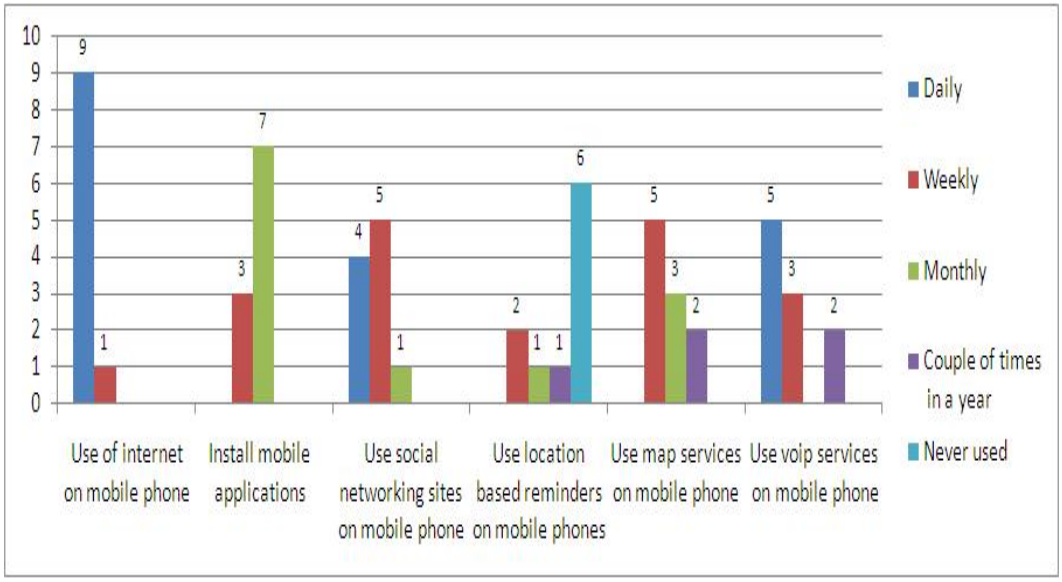

Figure 6.21: Results from SUXES Background Questionnaire

one is the worst face (male, 28)" and *"Difficult for me to distinguish between excited pleasant and calm pleasant (male, 24)"*. Even though, enough training is provided to the participants but still I am not able to make participants fairly comfortable in answering Emocard. The main reason behind this behaviour could be that almost all participants are new to user testing and Emocard in particular so participants may require more practice while testing new and fascinating methods like Emocard. This claim is further strengthen with the fact that none of the participant faced this difficult while performing Emocard based evaluation for the proof of concept. This may be due to their grown familiarity with this method.

All four prototypes received almost same evaluation results. The probable reason for this could be due to high amount of similarity between the prototypes because first two prototypes are almost same except having one added enhancement in second prototype. Fourth prototype complements first and second prototypes by displaying their content in form a mobile application. However, a deep analysis of the Emocard results shows that *"MMR N900 App"*, *"MR Street view"* and *"MR toggle street"* received higher pleasant responses compared to the MR Panorama.

Emotional response evaluation for the proofs of concept shows that language barrier received highest pleasant responses while MR indoor and MR outdoor are also fairly appreciated with pleasant responses. However, *"playfulness"* received calm unpleasant and excited neutral emotional responses.

"Interaction with MMR" is partially accepted by the participants. Majority of the participants appreciated first and third scenario while second is not taken well by the participants.

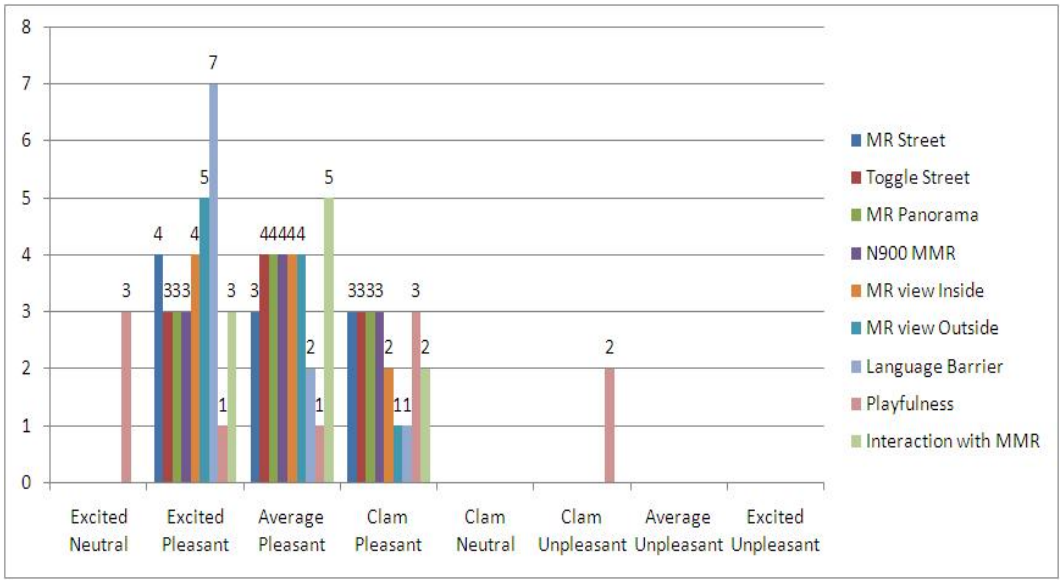

Figure 6.22: Emotional responses for MMR prototypes and proofs of concept

Qualitative feedback on Prototypes and Proof of Concept
Qualitative data provides feedback on how participants assessed the overall goodness of the prototype. Furthermore this data provides an insight on participants' thoughts and overall reasoning. Through the qualitative data, I am mainly interested in knowing-

1. Why users evaluated their emotions as they did in the Figure 6.22?
2. What other parameters have affected users' decision such as usefulness and needs?

Qualitative Findings on Prototypes
Emocard responses for *"MR Street view"* and *"Toggle Street view"* are almost similar but the qualitative data showed that participants considered "MR Street view" as nice, good concept and need further improvement. Participants expected more than simple location tagging and address representation. Some of the notable comments are *"Quite good I like the concept (male 24, MR Street prototype)"* and *"It should me more informative. The address thing is good. It is giving exact address (female 26, MR Street prototype)"*

"Toggle Street view" is considered much better, enhanced and useful compared to the "MR Street view". *"I think second one was good.....probably most intuitive and gives lot of good experience but about the 4th one (N900 MMR).....we already have application that help you connect with your friends and get information so probably it should be bit more different to differentiate from the existing ones (male 28, Toggle Street prototype)"* and *"No comments...it is almost the same but it gives probably better UX (male 26, Toggle Street prototype)"*.

"N900 MMR" prototype is recognised as nice to test and usage as expected. Prototype is seen as something familiar, already known and ordinary. The possible reason can be due to the use of Maemo Hildon UI guidelines for creating this prototype. Majority of the participants mentioned that UI for the prototype as simple and not so intuitive. Furthermore, some participants have categorised this MMR application layout similar to ordinary Nokia mobile applications. *"App looks just like other Nokia mobile app? (male,28) "* and *"N900 application uses ordinary Nokia Ovi buttons but if you use something else then it will be more intuitive (male, 26)"* .

Almost half of the participants doubt the practical utility of "MR Panorama". Furthermore, majority of participants regarded it as nice concept but not fully sure of its usefulness. *"I think it is probably good for interiors of a building but I doubt the practical utility like street view is highly used because people visit places but street view kind of information for interior looks new but surely try it (male, 28)"* and *"I am interested only in what restaurants are there in a city and what food they serve but I am least interested in looking where they serve the coffee and what kind of interior they have (male, 25)"*

Overall, quantitative comments reflect that participants would like to see richer content compared to the present one, something new in terms of application UI and look.

Qualitative Findings on Proof of Concept

Qualitative feedback received on *"MR indoor view"* and *"MR outdoor view"* showed that both concepts are appreciated but participants' expect more than just simple presentation of the information. Majority of participants mentioned that MMR should provide customization or personalization while showing the MR view. Some of the prominent responses are - *"Digital information on the buildings is informative but it should also provide further information like website of that building, direction, etc...Tags may include some more information (female 26, MR outside)"* and *"Intuitive way to tag places but these information tags should not appear all of a sudden rather information should pop only when you want it (male 28, MR outside)"*.

Participants do not consider having a virtual pet can increase the *"Playfulness"* and majority of them stated that virtual pet cannot become utility in their life so they do not feel the need for having and using this kind of feature. *"Instead of having virtual pet, I would like to see a virtual tutor who helps me in finding places where I can go for lunch, help me in my studies and talk with me when I feel boredom (26 male)"*, *"It is difficult for me to visualize how it is going to work, how it will be used in daily routine (male, 27)"* and *"It is fun and innovative but I don't see much utility (male 23)"*.

"Language barrier" is the most appreciated concept it is seen as pleasant, positive and useful. Participants' qualitative feedback has further strengthened this claim. *"Very much information, especially when you are going to china (female, 26)"* and *"Informative as language is a big barrier in this rising word so would be very much useful (male, 24)"*

Participants are positive on some of the aspects of the *"MMR interaction"* while neutral on others. *"It is useful for professional networking as well as for socialization but only if security issues are death with....Coffee shop and rating scenes are good as it gives a geo social experience (male 24)"* and *"I like rating and polling information...giving rating is good but I don't know how much useful it is to chat with strangers..So I don't like chatting with strangers (male, 26)"*

6.5.3 Analysis of Evaluations about Different Types of Prototypes

In this section, the analysis and comparison of AttrakDiff 2 and 3 is presented. AttrakDiff 2 assessed the hedonic and pragmatic attributes of users' interaction with MMR prototypes while AttrakDiff 3 judged these attributes in respect to MMR proofs of concept. Through the comparison of AttrakDiff 2 and 3, I can answer the following questions-

1. How users accessed their expectations towards the technology, prototypes and proofs of concept?

2. How users accessed their experience on the semi-functional prototypes and non-functional proofs of concept?

Both the above listed questions answer a methodological question i.e. *"How did the evaluations between the two groups of prototypes differ"*.

Pragmatic Quality (PQ) Comparison of the pragmatic qualities in the AttrakDiff 2 and 3 reflects following interesting facts (see Figure 6.23)- Pragmatic qualities such as appeal, motivation, boldness and innovativeness

became stronger after interacting with proofs of concept. The possible reasons can be that proofs of concept has further concretized the whole concept of MMR. Furthermore, proofs of concept differs from prototypes in terms of the hosted content and utility. This fact may also affect the participants' decision.

Pragmatic qualities such as structured, challenging and novel remain exactly the same in both evaluations. This reflects that participants' considered MMR as a novel and structured concept. However the important observation is that although prototypes and proofs of concept have different level of interaction and content but still there is no change in the opinion of the participants.

Prototypes are considered more manageable and captivating compared to proofs of concept. The obvious reason is that level of completeness of the shown prototypes. As the prototypes more interactive and practical complete so due to this, participants may have considered them as more manageable and captivating compared to the proofs of concept.

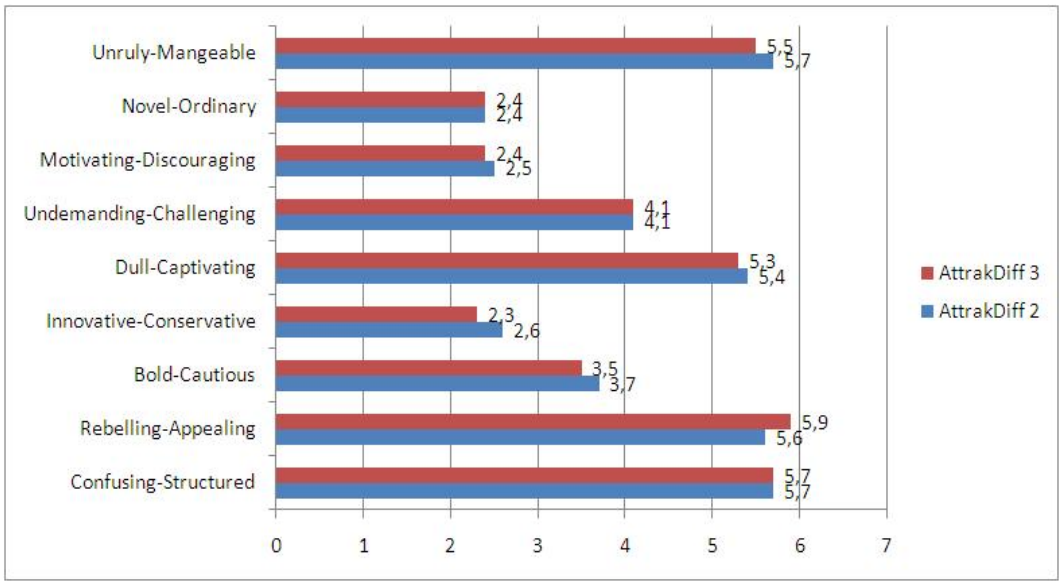

Figure 6.23: Comparison of PQ between AttrakDiff 2 and AttrakDiff 3

Hedonic Quality Identification (HQI) The comparison of HQI in the AttrakDiff 2 and 3 is presented below (see Figure 6.24). Prototypes are considered as more stylish, presentable and bring people closer compared to the proofs of concept. The supporting reason can be due to higher level of

completeness of prototypes against non-functional nature of proofs of concept.

Both the proofs of concept and prototypes received equal HQI rating for *"good"* and *"integrating"*. This clearly shows that MMR is overall considered having a good factor and it integrates its users socially.

Prototypes are recognised as less creative, inviting, premium and predictable compared to proof of concept. The probable reason is due to the fact that proof of concept represents futuristic scenarios that are more creative while prototypes represent somewhat ordinary approach. The reason for receiving less on predictable, premium and inviting may be due to the fact that participants built more understanding on MMR in general and this understanding became more concretized with the time.

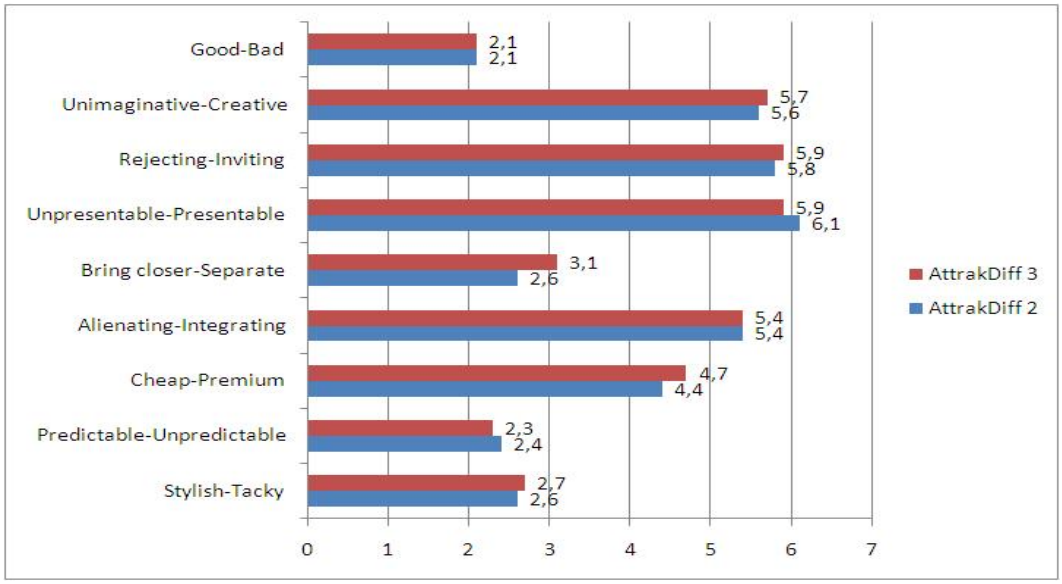

Figure 6.24: Comparison of HQI between AttrakDiff 2 and AttrakDiff 3

Hedonic Quality Stimulation (HQS) The comparison of HQS in the AttrakDiff 2 and 3 is discussed in Figure 6.25. Proofs of concept are recognized as straightforward, likeable, attractive, professional, simple, inventive, connective and human compared to the prototypes. The probable reason could be due to the fact that proofs of concept are simple looking, non-functional and do not possess any kind of interaction with the mobile phone unlike the prototypes.

Prototypes are considered more practical and pleasant against proof of concept. The obvious reason is that prototypes are semi-functional and pro-

vide different level of interactions so this reflects than MMR is practically realizable compared to proof of concept which are just illustrations. Furthermore, first time experiences are always more pleasing compared to ordinary and in routine experiences so this may the possible reason why prototypes gave more pleasant experience compared to the proof of concept.

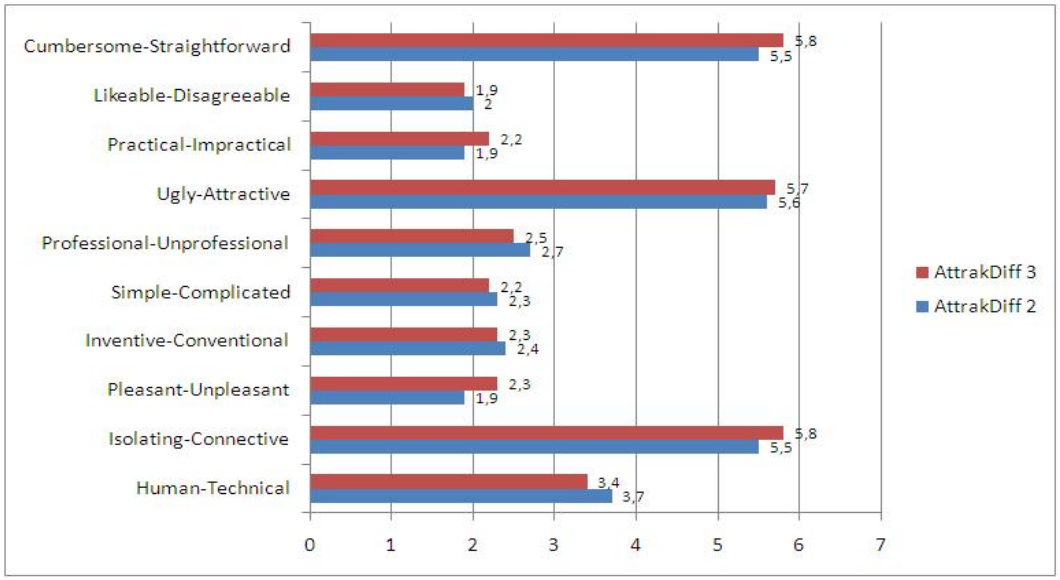

Figure 6.25: Comparison of HQS between AttrakDiff 2 and AttrakDiff 3

6.5.4 Analysis of Expectation versus Actual Use Experience

In this section, results from the analysis of expectation versus felt or actual use experience are presented. The objective of this analysis is to answer the following question- *"How did the actual experience differ from expectations?"* This is also a theoretical question related to general challenges in UX theories. This question can be ansared as follows - First by presenting the analysis of expectations versus expectations based on SUXES questionnaire. Second, comparing data received from AttrakDiff 1 versus AttrakDiff 2 and 3. Both these analysis will answer the main theoretical question stated above.

SUXES is known for measuring the temporal UX by the evaluation of pre-use expectations and post-use experiences. SUXES questionnaires on expectations and perception make it possible to evaluate *"how well participants' expectations have been met"*. The results of SUXES analysis can be complemented through the AttrakDiff results. I presented the comparison of

expectations versus perception by using AttrakDiff results where AttrakDiff 1 presents the users' expectations from MMR while the average of AttrakDiff 2 and 3 represents the use experience after evaluating MMR prototypes and proof of concepts.

Expectation versus Use Experience based on SUXES
SUXES method consists of two questionnaire called expectation and perception questionnaires. Both the questionnaires produce three values for each statement. These values enable me to find the gap between the expectations and experiences. This gap is represented using two disconfirmation measures namely Measure of Service Superiority (MSS) and Measure of Service Adequacy (MSA). The first measure MSS is calculated as a difference of perceived and the desired level while second measure MSA is equivalent to the different between the perceived and accepted level. If experiences are in the range of expectations or in other words inside the scale of ZOT, MSA is positive (meaning perceived rating is more than acceptable level) and MSS is negative (meaning desired level rating is more than perceived level) then it is concluded that participants' expectations have been very well met. [64]

For example, for the statement *"MMR connects me with people"*, participants responded as *"acceptable = 4"*, *"desired = 7"* and *"perceived = 5"*. Then ZOT will lie between 4 and 7, MSS = -2 and MSA = 1.

Figure 6.26 presents the SUXES results through MSS, MSA, and ZOT, acceptable, desired and perceived value. This perceived value denote the UX or use experience. The result shows that expectations of the participants are very well met for all ten different SUXES metrics. The reason is due to the fact that perceived use experience for all ten metrics is in the range of ZOT, MSA is positive and MSS is negative.

SUXES results have validated that participants considered MMR prototypes and proof of concept provides *"Different possibilities for interaction (MSS = -0.4, MSA = 1.1)"*, *"Fast to use (MSS = -1.1, MSA = 0.5)"*, *"Useful in daily life (MSS = -0.7, MSA = 0.9)"*, *"Intuitive easy (MSS = -0.5, MSA = 0.8)"*, *"Simple to use (MSS = -0.3, MSA = 1.4)"*, *"Usage at public places acceptable (MSS = -0.1, MSA = 1.1)"*, *"Stylish style statement (MSS = -0.4, MSA = 0.5)"*, *"Fascinating to use (MSS = -0.4, MSA = 1.1)"*, *"Connecting with other people (MSS = -0.3, MSA = 1.4)"* and *"Innovative technology (MSS = -1.1, MSA = 0.6)"*

Expectation versus Use Experience based on AttrakDiff
In the UX evaluation study, AttrakDiff is answered by the test participants three times as follows - AttrakDiff 1 before actually testing the prototypes and proof of concepts. AttrakDiff 1 helps in evaluating the hedonic and

Metrics	Acceptable	Desirable	UX	ZOT	MSS	MSA
Diff possibilities of interaction	4,8	6,3	5,9	<4,8 - 6,3>	-0,4	1,1
Fast to use	4,6	6,2	5,1	<4,6 - 6,2>	-1,1	0,5
Useful in Daily Routine	4,4	6	5,3	<4,4 - 6>	-0,7	0,9
Inituituve & easy	5,1	6,4	5,9	<5,1 - 6,4>	-0,5	0,8
MMR is simple to use	4,7	6,4	6,1	<4,7 - 6,4>	-0,3	1,4
Usage at public places & acceptable	4,8	6	5,9	<4,8 - 6>	-0,1	1,1
Stylish & style statement	4,4	5,3	4,9	<4,4 - 5,3>	-0,4	0,5
Fascinating to use	5,1	6,8	5,2	<5,1 - 6,8>	-1,6	0,1
Connecting with other people	4	5,7	5,4	<4 - 5,7>	-0,3	1,4
Innovative Technology	4,7	6,4	5,3	<4,7 - 6,4>	-1,1	0,6

Figure 6.26: Results of SUXES questionnaire on Expectation versus Use Experience

pragmatic expectations of the users. Later AttrakDiff 2 is filled after evaluating all the prototypes and AttrakDiff 3 is answered after testing proof of concept. Average of AttrakDiff 2 and 3 helps in evaluating the post-use experience of the participants. AttrakDiff 1, 2 and 3 had same questions but only difference is in different timing for answering. AttrakDiff metrics measures different aspects compared to SUXES metrics. Due to the use of triangulation principle in applying different UX research methods, AttrakDiff data supports the *"expectation versus experience"* analysis of the SUXES results.

Pragmatic Quality (PQ) The comparison between PQ expectations and perceptions is shown in Figure 6.27. Participants considered MMR as innovative, novel, manageable, motivating, captivating and appealing in their expectations but after interacting with prototypes and proof of concepts, MMR is regarded as conservative, ordinary, unruly, discouraging, dull and rebelling. However, overall MMR is still regarded as innovative, novel, manageable, motivating, captivating and appealing in their use experience. The possible reason may be due to the fact that products often become less captivating, novel, appealing after repeated use as studied in different theories on UX.

Other than this, participants recognised MMR as structured, undemanding and bold in the use experience compared to confusing, challenging and cautious in their expectations. The possible reason may be due to the use of concrete and realizable prototypes as stimuli helped participant in further

understanding MMR. Furthermore, participants started thinking MMR as utility as reflected by the pragmatic quality adjectives.

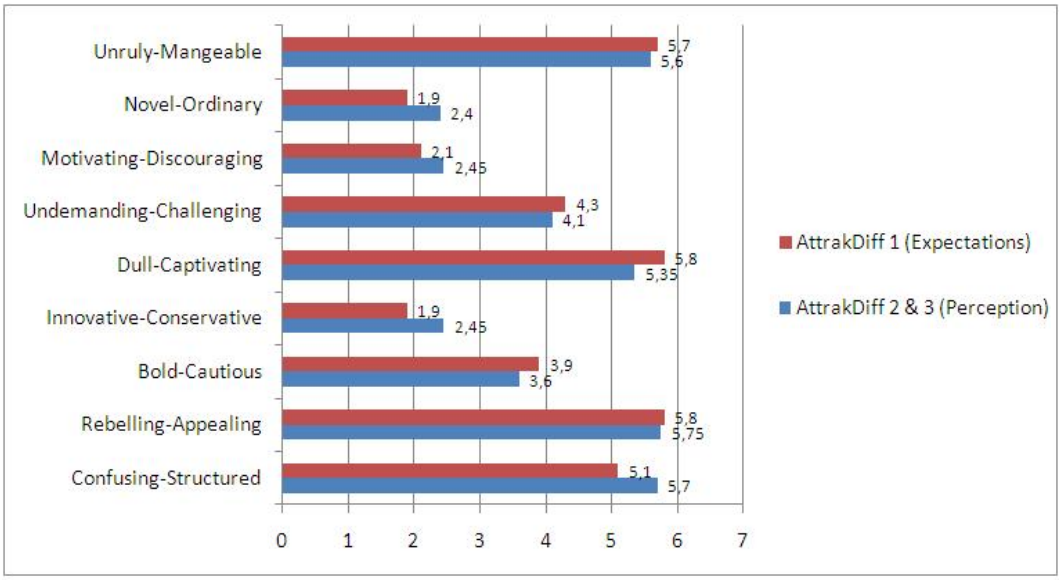

Figure 6.27: Comparison of PQ between AttrakDiff expectations and perceptions

Hedonic Quality Identification (HQI) The comparison between HQI expectations and perceptions is shown in Figure 6.28. Participants considered MMR as inviting, integrating, good, bring closer, predictable, presentable, stylish and cheap in the use experience against considering bad, rejecting, un-presentable, separate, integrating, premium, unpredictable and tacky in their expectations. The reason behind this change is due to the fact that while answering expectation, participants are not aware with the other possible MMR use cases, concepts and prototypes so they had only limited interpretation about MMR. However the use different kinds of prototypes and proof of concepts made participants to believe that MMR is something that can is realisable; socially connect them with others, creative and novel technology. Other than this, one interesting fact is noticed that unlike other responses, participants considered MMR as unimaginative in their perception against being creative in their expectation. The reason behind this change may be due to futuristic looking proof of concepts; participants changed their opinion and considered MMR as unimaginative in the end of the UX study.

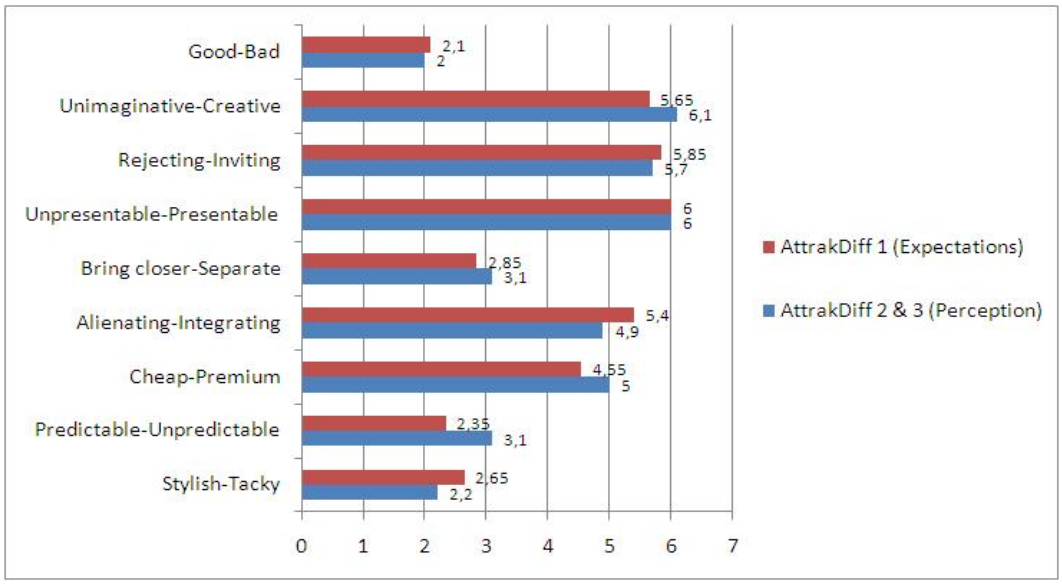

Figure 6.28: Comparison of HQI between AttrakDiff expectations and perceptions

Hedonic Quality Stimulation (HQS) The comparison between HQS expectations and perceptions is shown in Figure 6.29. Participants regarded MMR as straightforward, likeable, practical, simple, pleasant and human in their use experience against considering cumbersome, disagreeable, impractical, complicated, unpleasant and technical in their expectations. This change in opinion may be due to the understanding built after interactive with semi functional prototypes and proof of concepts. Participants' opinion becomes more concrete after this interaction. Prototypes used for the UX evaluation have very well presented different aspects of MMR use such as context and interaction. Other than these, analysis of the HQS shows that MMR became ugly, unprofessional, conventional and isolating in the users' perception. Again the reason is same as I explained before that product often become less attractive, unprofessional and lesser inventive after their repeated use.

6.6 UX Evaluation Summarized

Product designers can greatly benefit from the UX evaluation process as it helps in determining the gap between the user expectations and use experiences. In this chapter, I evaluated the UX of four semi-functional prototypes and five non-functional proofs of concept by using UX evaluation methods

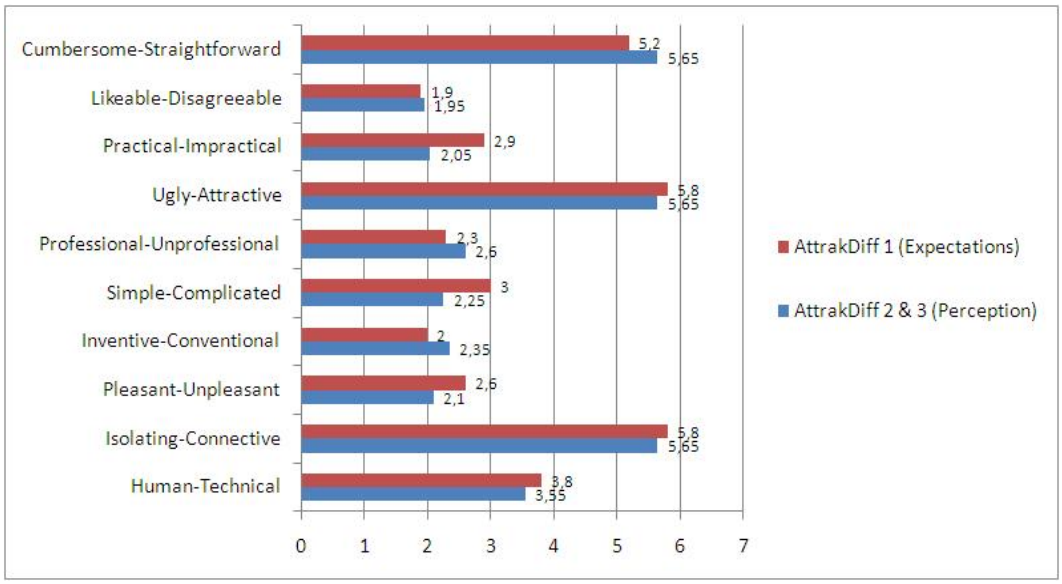

Figure 6.29: Comparison of HQS between AttrakDiff expectations and perceptions

such as SUXES, Emocard and AttrackDiff. Triangular research principal is followed in practicing this UX evaluation study containing three different methods that complement each other. Through this integration, I am able to evaluate users' objective, subjective and emotional response for every prototype and proof of concept.

The analysis of the Emocard emotional responses and qualitative feedback showed that Emocard alone is not sufficient in explaining the reasons for *"why the participants evaluated their emotions in a particular way"* and *"what parameters have affected their decision while answering Emocard"*. These questions can only be answered by complementing Emocard study with some post qualitative measures such as interviews, as I did in this evaluation study. This serves as a perfect example of triangulation principle.

Similar to Emocard other two methods i.e. AttrakDiff and SUXES also suffer from this drawback. SUXES and AttrakDiff can quantitatively assess the hedonic and pragmatic attributes of the users' interaction with the MMR prototypes and proofs of concept. But for reasoning and explaining certain patterns, I require some qualitative data. Due to this reason, short interview sessions are performed at different phases of this UX evaluation study.

There are two goals behind this UX evaluation study as mentioned in the beginning of this chapter. For achieving the first goal, I implemented semi-functional and non functional prototypes by using different visualization

techniques. After this, three different UX evaluation methods are thoroughly studied and a study methodology based on triangulation principle containing these three UX evaluation methods is designed. Finally UX evaluation study is performed with ten participants. Keeping in mind the second goal, all the interview sessions are listened and qualitative responses are noted. These qualitative data gave rich insight on the different elements that affect the users' expectations and perceptions in regard to the shown prototypes and proofs of concept. In this way, both goals of this UX evaluation study are achieved.

In the study results, it is found that concreteness and realizability, type and level of the interaction supported, personalization of hosted content, novelty, intuitiveness in the design and usefulness are some of the deciding factors for the usersâ expectations and perceptions in regard to MMR prototype and concept.

Chapter 7

Discussion

In this chapter, discussion on the study results and its contribution is presented, validity and reliability of the presented study is described. In section 7.1, thesis results and their contribution is discussed, relevance to literature review, feature triangle and thesis title are described. In section 7.2, methodological discussions are presented by first describing the main objective and research questions of this thesis and later answering them. Finally in section 7.3, validity and reliability of this research is discussed.

Today users are interesting in using those products that are easy, intuitive, visually appealing and pleasurable in use. It has now become essential for product designers to fulfill users' needs, expectations and requirements. UCD and UX are now recognized as crucial elements that should be considered when developing and designing products or services. Furthermore their role in product development has changed from *"should be"* to *"must be"* considered. Below, I discuss the relevance of different claims that I made in the theoretical and empirical chapters of this thesis.

7.1 Discussing the Results and Contribution

Relevance to Reviewing AR Literature and Feature Triangle
The review of existing AR applications, creation of feature triangle and preparing the summary of requirement for future MMR application helped me in the investigation of UCD-UX research theme from a wider point of view. This kind of theoretical and empirical background research is rarely done by anyone in context to designing MMR user centered products. I presented seven key requirements for a future MMR application out of which I used six of them in my semi-functional prototypes, i.e. multiplayer, 3D maps, 2D map, geo tagging, and location based and playfulness. Audio channel as

a means for an alternative communication channel is not explored due to the semi-functional nature of the prototypes. Furthermore having alternate channels such as ambient radio and audio for countering GPS errors and network disturbances requires extensive development and user testing in real settings. This is difficult for me, keeping in mind the thesis schedule and having so many empirical phases in the current thesis.

Relevance to Title of the Thesis

During the UX evaluation of the prototypes and proofs of concept, it is found interestingly that most of the user opinions and feedback revolve around three aspects of any application, i.e. social aspects, experience and design. This fact has validated the authenticity of the feature triangle created by me. The title of this thesis i.e. *"People, Product and Experiences"* depicts my overall approach that I have followed at different theoretical and empirical phases of this thesis. Furthermore, all prototypes and proofs of concept received high grade in subjective, objective and emotional UX evaluation. This fact also proven the validity of the UCD methodology that I practiced and feature triangle that I created.

Methodological contribution

To the best of my knowledge, UX of MMR has mostly been studied by Olsson et al. [53]. The existing studies mostly focused on understanding user expectations through the use of limited number of use cases and types of interaction. In contrast to the existing work, my work is a further extension of it. Similar to the existing work, I studied user needs and expectations. Based on this knowledge, I constructed different semi-functional and non-functional prototypes to concretize and visually describe MMR concept to the potential users. This is the clear novelty of the empirical UCD practiced by me. Furthermore, I performed UX evaluation of the created prototypes by using three different UX methods. All these methods have been used before but my work is the first one in the domain of MMR.

Traditional UCD research methods such as focus group, questionnaire and observation are competent in studying current practices and problems related to them. Furthermore traditional UCD methods can very well identify user needs but when the focus is in the future then these are challenging to use. This problem is solved by *"Lost foreigner"*, a cost effective user research method. It can help in quickly collecting user needs and expectation but the validated and authenticity of the results gathered by this method are unknown. However, I believe that *"Lost foreigner"* can be helpful in the development of products based on futuristic and novel technologies like MMR.

7.2 Methodological Discussion

The main objective behind this thesis is to *"design potential MMR concepts though User Centered Design (UCD) methodology and evaluate their User Experience (UX)"*. This objective is further concretized through four main research questions namely -

1. What are the users' needs and expectations to this technology?
2. What kind of MMR concepts seem most appealing to the users?
3. What methods are the most suitable for evaluating UX of the designed MMR prototypes and proofs of concept?
4. What are the challenges of creating concepts based on new technologies?

The main objective and above listed research questions are answered as follows -

What are the users' needs and expectations to this technology? Studying user needs and expectations is essential not only for designing usable product but also for creating concepts for futuristic and novel technologies like MMR. Furthermore, understanding user expectations can potentially help in the approximation of the UX. To address this, I performed both intensive and extensive UCD empirical study for designing potential MMR concepts. I created four semi-functional prototypes and five non-functional proofs of concept that are used for evaluating UX.

Users' needs and expectations are broadly gathering while practicing empirical UCD and evaluating UX. The review of existing AR applications and literature helped in getting started with the UCD. Focus group discussions are the first point of contact with the users so most of the needs and expectations are collected at that stage. Four different focus groups are conducted containing all kinds of future MR users. To interpret the user data, affinity diagrams and design drivers are made. The process of affinity diagram is instrumental in finding the users' needs, requirements and expectations from MMR applications. Later, affinity diagram results are used for designing prototypes and proofs of concept on MMR.

It found that users' expectations are mostly pragmatic but it also includes hedonic aspects. Some of the notable pragmatic needs are personalization, instant service, relevant and meaningful content, usefulness in daily practices, effortless, handy, and usable. At this stage very few hedonic expectations are

reported. Most common one is intuitiveness of the MMR. The reason behind having only pragmatic expectations at this stage is due to the fact that scenarios and use cases shown during focus group are not concrete enough for the participants so that they can thing beyond the current level of expectations.

Apart from these, users raised several questions related to the privacy and other risks associated with MMR use, reliability and freshness of the presented information, social awkwardness while using MMR and paying for MMR service as possible restrictions to its adoption. Less common concerns are running out of battery due to MMR use and cracking of MMR during critical situations.

During UX evaluations, majority of the expectations are hedonic in contrast to the pragmatic expectations. Most of the reported expectations are MMR should be stylish, intuitive, unconventional, tacky appearance and so on. The pragmatic expectations are almost same at they are during the focus interview.

Overall empirical UCD and UX evaluation part of this thesis are surely a success due to following reasons- First, results from the empirical UCD supports the previous research results in this area. Second, almost all prototypes and proofs of concept received high user acceptance and appreciation. This shows that my prototypes and proofs of concept meet user needs and expectations.

What kind of MMR concepts seem most appealing to the users? During empirical phase of the UCD, participants gave extensive amount of design ideas, concepts and potential use cases for MMR. Some of them are practically realizable while mostly are futuristic in their appeal. Majority of these concepts and use cases are broadly related to sense of utility, relevance and personalization. This results in saying that user appreciates those concepts that make their present life easier, possess utility, relevance and personalization. Based on these expectations, I created altogether nine prototypes that are tested by users during UX evaluation. I found that *"MR Street view"*, *"MR Toggle view"* and *"MMR N900 app"* are appreciated by the users because of their completeness, realizability, meeting their needs and expectations and possesses something new in terms of design and functionality. *"Language barrier"* is highly appreciated among all the nine prototypes due to the presence of high utility while *"playfulness"* is rejected by users because it lacks in the element of utility.

"MR indoor view" and *"MR outdoor view"* are considered pleasant and nice but having almost similar supported functionalities. Both are appreciated because they are simple looking, possess utility and novelty. First and third scenario of *"MMR interaction"* is appreciated by users but the third

scenario having chatting with stranger did not work well with the participants. Several articipants doubt the practical utility of *"MR Panorama"*. It was regarded as nice concept but lacks usefulness.

What methods are the most suitable for evaluating UX of the designed MMR prototypes and proofs of concept?
Emocard method can be used for evaluating both functional and non functional prototypes but alone Emocard is not be suffice as product designers are also interesting in knowing the reasons for a particular type of emotional response so it must include some kind of post evaluative procedure similar to what I used i.e. structured interviews for accessing their overall reasoning on how users evaluated particular prototypes. Pilot study showed that Emocard faces are difficult for users to recognize and answer but due to the additions that I made it, whole study became easier. During the UX evaluation tests, Emocard is found intuitive and fascinating for the participants; this is partially due to the added textual description to its different faces and training given before its testing.

SUXES is efficient way of mining interesting data about any product or service with a reasonable effort. Previously, SUXES has been used only in the subjective evaluation of speech based and other modalities in multimodal applications. In contrast to the original SUXES, my adapted version is both challenging and novel as our application area is MMR which is a futuristic technology. SUXES is special in case of MMR interactive application because it helps in collecting of users' expectations that in a way provides context for determining UX. These expectations can actually show how important are certain factors for users, thus SUXES providing some insights into how the future users will perceive MMR. SUXES method is competent in evaluation the pre use expectations and post use experience of any prototype. A qualitative feedback is required to further concretize the resulting claims of SUXES.

AttrakDiff questionnaire is potentially efficient when used for the UX evaluation of the almost ready product or prototype. Many statements in this questionnaire fit only to the evaluation of nearly complete product. I used AttrakDiff at three different stages and it is found during the evaluation study that AttrakDiff is competent in elicitation of user expectations when tested against the concrete prototypes or proofs of concept.

Triangulation research principle greatly increases the authenticity and validity of the study methodology. During this thesis, I realized that due to triangulation of different UCD research and UX evaluation methods, I is able to provide a balancing effect on the overall study. This finally enabled me to practice a richer, reliable and valid study.

All these evaluation methods are only successful if the test users are fully trained for using them. A product designer cannot fully utilize the benefits of these methods if the test participant does not understand different adjectives, word pair and scales used in these methods.

What are the challenges of creating concepts based on new technologies?
During the literature review, I found that many authors quoting *"it is challenging to perform UCD if the technology is futuristic"*. This is my first contact with an open research problem i.e. *"designing for novel and futuristic technology based on user needs and expectation"*. During the empirical UCD, I found that it is challenging for the participants to picture the whole concept of MMR when less concrete solutions are provided to them. Majority of the participants find it difficult to answer questions related to the affordability and routine use of MMR in the beginning of the discussion. To solve this challenge, I made two important additions - First, different types of stimuli are introduced during the discussions such as use of scenario, storyboard, video, textual and pictorial representations for the potential ideas. Second, all the use cases, tasks and scenarios are kept present-day so that participants consider MMR as something realizable and a practical utility in their daily life.

After performing the focus group interviews, I felt the need for having more concrete concepts or prototypes that can act as stimulus during such discussions. I fulfilled this gap during UX evaluation where interviews are also conducted along the UX testing. I found that my UX evaluation study is greatly benefitted with the use of concrete and visual semi-functional and non-functional prototypes.

7.3 Validity and Reliability of the Study

The overall research process is qualitative by nature so it is natural to have questions on its validity and reliability. It is important that if this whole study is repeated by some other researchers or UCD-UX practitioners then it could produce similar results. This fact comes with a precondition that the other researcher or practitioner should have precise knowledge on the research questions, different sessions performed during empirical UCD and UX evaluations and finally on the user group. However, when studying a new technology like MMR which is both futuristic and novel then it is challenging to find the real reasons for users' actions. There can be several factors that may influence user's opinion and decision especially when the technology in

discussion is futuristic. Furthermore, in my study the studied user population is narrow as it represents majority of technical students so it is impossible to generalize these results to cover whole population.

The different phases presented in this thesis are performed individually by me so there are great changes that my prior knowledge has biased the whole study results. This is due to the influence of a single person in data gathering, prototype designing and implementation and UX evaluation. Furthermore, individual users can also influence the results. Hence the results presented in this thesis can be called biased with the researcher's own prejudices, hypothesis and background. However, there are several arguments that can prove the validity and reliability of the presented results even through only a single person is involved in study. First, total of 15 users have participated in the empirical UCD and 10 users took part in UX evaluation. Furthermore in both these phases, different users are recruited hence using several different users in both phases, diminished individual user's influence on the study results. Second, affinity diagram are carried out in group of three so design drivers are not only decided by me. Third, empirical UCD study results are similar to Olsson et al. [53] so this has proved the credibility of UCD practiced by me. Finally, triangulation of various UCD and UX research approaches has reduced this bias to some extent.

Due to all these reasons, the results became more reliable and valid for other researchers and practitioners.

Chapter 8

Conclusion and Future Work

In this last chapter a brief summary of results from this thesis is presented, importance and novelty of the different empirical parts of this thesis are discussed. Finally important ideas for future work are discussed.

Studying user expectations potentially help in designing UX and this fact has been validated in this thesis. The main output of this thesis is to develop semi-functional prototypes and non-functional proofs of concept on a futuristic technology like MMR based on user needs and expectations. Later the developed prototypes and proofs of concept are used to access and improve their UX through different UX evaluation methods. The results of this thesis can used an example for application developers, UX practitioners, researchers and consumer companies.

MMR can provide rich, pleasing, enjoyable and positively surprising experiences to its users. Application developers who are interested in exploiting the opportunities provided by MMR should understand the importance of studying user needs and expectations before actually implementing a product based on MMR. The adapted UX evaluation methods, study methodology and results from the UX evaluation can provide crucial insights for UX practitioners who are interesting is practicing objective, subjective and emotional response evaluations. The research results from the empirical UCD and UX evaluation lifecycle are potentially useful for further research in the science community. Furthermore, the results can be utilized by consumer companies interested in implementing and commercializing the MMR technology.

So far the research on this topic is limited only to understand user needs and expectations through the use of limited number of use cases and types of interaction. However in this thesis, the existing work is further extended through the triangulation of UCD and UX research approaches in order to develop concrete demonstrators on MMR.

Overall UX of a product based on MMR is affected by the factors such as

personalization and relevance of the shown information, novelty of the ideas, intuitiveness of the design and utility of the product in daily routine.

8.1 Future Work

This thesis has described the methodology, results and insights for UX evaluation of prototypes and proofs of concept that are based on a futuristic technology i.e. MMR and developed using UCD methodology. One new method is purposed for collecting user opinions and feedback which can be easily implemented for other applications areas too. Three existing UX evaluation methods are adapted to meet the requirements of thesis. An extensive UCD and UX evaluations are performed to answer the research questions behind this thesis.

The combination of UCD and UX research methodology followed in this thesis can easily be implemented for developing prototypes and proofs of concept for other novel and futuristic technologies. However, the present UX evaluation methodology requires further extensive validation of the results.

All the prototypes and proofs of concept received high grade and higher acceptance from the test participants because user needs and expectations are understood before actual development. Furthermore UCD methodology greatly helped in elicitation of the user expectations from MMR in my designs. However, the present user acceptance for the prototypes and proofs of concept can be made even better by further improving the present designs, making them ready in terms of functionality and appearance.

The performance of UX evaluation methods such as Emocard and AttrakDiff greatly depends upon the level of training giving to the participants. This becomes even more important when test participants are not native English speakers. Those factors that can potentially affect performance of any UX evaluation require further investigation. This kind of investigation can surely benefit other UX evaluation methods and UX research in general. SUXES evaluation method needs further development and validation such as making it fully automated in order to reduce human effort and significantly increasing the amount of data. Lost foreigner requires further improvement as the information gained through its present form is not very rich. There is one concern regarding the validity of this method as there are some social rules on how to behave, so people may not say their real opinion about the concept. Future work may include improving lost foreigner method by examining different concerns on its validity through field studies.

Bibliography

[1] Geo-Tracing Software Platform. http://www.geotracing.com/ Last visited on 04,Feburary,2011.

[2] Pac-Manhattan. http://www.pacmanhattan.com/ Last visited on 04,Feburary,2011.

[3] Spiggle, S., *Analysis and Interpretation of Qualitative Data in Consumer Research* , Journal of Consumer Research, December 1994, pp. 491-503

[4] ISO/IEC. 13407 Human-Centred Design Processes for Interactive Systems, 1999, Switzerland International Organisation for Standardization(ISO).

[5] ISO 9241-210, 2009. Ergonomics of Human System Interaction - Part 210: Human Centred Design for Interactive Systems (formerly known as ISO 13407), Switzerland International Organisation for Standardization(ISO).

[6] Agarwal, A., and Meyer, A. Beyond usability: evaluating emotional response as an integral part of the user experience. In *Proceedings of the 27th international conference extended abstracts on Human factors in computing systems* (New York, USA, 2009), CHI Extended Abstracts, ACM, pp. 2919–2930.

[7] Azuma, R. T. 1997 A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments. vol. 6, No. 4, pp. 355–385.

[8] Bach, C., and Scapin, D. L. 2004 Obstacles and Perspectives for Evaluating Mixed Reality Systems Usability Acte du Workshop MIXER, IUI-CADUI'04.

[9] Beyer, H., and Holtzblatt, K. Contextual design. *Interactions 6* (New York, USA, January 1999), vol. 6, pp. 32–42.

[10] Beyer, H., and Holtzblatt, K. *Contextual Design. Defining Customer Systems.* Morgan Kaufmann Publishers Inc., San Francisco, CA, USA. pp. 472, 1998.

[11] Bødker, S. Scenarios in User-Centered Design - Setting the Stage for Reflection and Action In *Proceedings of the Thirty-Second Annual Hawaii International Conference on System Sciences - Volume 3* (Washington, DC, USA, 1999), IEEE Computer Society, pp. 3053–3064.

[12] Brave, S., and Nass, C. The Human-Computer Interaction Handbook. L. Erlbaum Associates Inc., Hillsdale, NJ, USA, 2003, ch. Emotion in human-computer interaction, pp. 81–96.

[13] Brown, B., Maccoll, I., Chalmers, M., Galani, A., Randell, C., and Steed, A. Lessons From The Lighthouse: Collaboration In A Shared Mixed Reality System In *Computer Human Interaction* (2003), pp. 577–584.

[14] Cheok, A. D., Goh, K. H., Liu, W., Farbiz, F., Teo, S. L., Teo, H. S., Lee, S. P., Li, Y., Fong, S. W., and Yang, X. Human pacman: a mobile wide-area entertainment system based on physical, social, and ubiquitous computing. In *ACM International Conference Proceeding Series* (2004), vol. 8, pp. 360–361.

[15] Desmet, P. *Measuring emotion.* Funology: From usability to enjoyment, Kluwer Academic Press, Dordrecht, Hingham, MA, 2003.

[16] Dünser, A., Grasset, R., and Billinghurst, M. A survey of evaluation techniques used in augmented reality studies. In *ACM SIGGRAPH ASIA 2008 courses* (New York, USA, 2008), SIGGRAPH Asia '08, ACM, 27p.

[17] Erevelles, S. The Role of Affect in Marketing. *Journal of Business Research vol. 42*, no. 3 (1998), pp. 199–215.

[18] Flintham, M., Benford, S., Anastasi, R., Hemmings, T., Crabtree, A., Greenhalgh, C., Tandavanitj, N., Adams, M., and Row-farr, J. Where on-line meets on the streets: experiences with mobile mixed reality games. In *Computer Human Interaction*, pp. 569–576.

[19] Flynn, B. B., Sakakibara, S., Schroeder, R. G., Bates, K. A., and Flynn, E. J. Empirical research methods in operations management. *Journal of Operations Management vol. 9*, no. 2 (1990), pp. 250–284.

[20] Forlizzi, J., and Battarbee, K. Understanding experience in interactive systems. In *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques* (New York, USA, 2004), DIS '04, ACM, pp. 261–268.

[21] Forlizzi, J., and Ford, S. The building blocks of experience: an early framework for interaction designers. In *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques* (New York, USA, 2000), DIS '00, ACM, pp. 419–423.

[22] Gulliksen, J., Göransson, B., Boivie, I., Blomkvist, S., Persson, J., and Cajander, Å. Key Principles for User-Centred Systems Design. *Behaviour & Information Technology vol. 22* (2003), pp. 397–409.

[23] Gurd, J. Can augmented reality be a commercial success for e-commerce?, March 24 2010. http://econsultancy.com/uk/blog/5637-can-augmented-reality-be-a-commercial-success-for-e-commerce

[24] Hassenzahl, M. *The thing and I: understanding the relationship between user and product.* Kluwer Academic Publishers, Norwell, MA, USA, 2004, pp. 31–42.

[25] Hassenzahl, M. The interplay of beauty, goodness, and usability in interactive products. *Human Computer Interaction. vol. 19* no. 4 (December 2008), 319–349.

[26] Hassenzahl, M., and Tractinsky, N. User experience - a research agenda. *Behaviour & Information Technology vol. 25* no. 2 (2006), 91–97.

[27] Hassenzahl, M. B. M. . K. F. Attrakdiff: Ein fragebogen zur messung wahrgenommener hedonischer und pragmatischer qualität. B. G. Teubner, Ed., Proceedings of Mensch & Computer 2003: Interaktion in Bewewgung. Stuttgart, pp. 187–196.

[28] Heikkinen, J., Olsson, T., and Väänänen-Vainio-Mattila, K. Expectations for user experience in haptic communication with mobile devices. In *Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services* (New York, USA, 2009), MobileHCI '09, ACM, pp. 28:1–28:10.

[29] Herbst, I., Braun, A.-K., McCall, R., and Broll, W. Timewarp: interactive time travel with a mobile mixed reality game. In

Proceedings of the 10th international conference on Human computer interaction with mobile devices and services (New York, USA, 2008), MobileHCI '08, ACM, pp. 235–244.

[30] Holtzblatt, K., and Beyer, H. Making customer-centered design work for teams. *Communications of the ACM 36 vol. 36* (October 1993), pp. 2592–103.

[31] J., N. *Heuristic Evaluation, Usability Inspection Methods.* Wiley & Sons Inc., New York, USA., 1994, pp. 25–62.

[32] Järvinen, P., and A. Järvinen *On Research Methods.* Tampere, Finland: Opinpajan Kirja, (2004). 204p.

[33] Jick, T. D. Mixing qualitative and quantitative methods: Triangulation in action. *Administrative Science Quarterly vol. 24, no. 4, Qualitative Methodology* (December, 1979), pp. 602–611

[34] Jordan, P. W. *Designing Pleasurable Products:An Introduction to the New Human Factors.* Taylor & Francis, London, UK, 2000. 216p.

[35] Kankainen, A. UCPCD: user-centered product concept design. In *Proceedings of the 2003 conference on Designing for user experiences* (New York, USA, 2003), DUX '03, ACM, pp. 1–13.

[36] Kaplan, B., and Duchon, D. {Combining qualitative and quantitative methods information systems research: a case study *Management Information Systems Quarterly vol. 12* (December 1988), 571–586.

[37] Karapanos, E., Hassenzahl, M., and Martens, J.-B. User experience over time. In *CHI '08 Extended Abstracts on Human factors in computing systems* (New York, USA, 2008), ACM, pp. 3561–3566.

[38] Karat, J., Atwood, M. E., Dray, S. M., Rantzer, M., and Wixon, D. R. User centered design: quality or quackery? In *Conference companion on Human factors in computing systems: common ground* (New York, USA, 1996), CHI '96, ACM, pp. 161–162.

[39] Kitzinger, J. The methodology of focus groups: the importance of interaction between research participants. *Sociology of Health & Illness vol. 16*, no. 1 (1994), pp. 103–121.

[40] Koleva, B., Taylor, I., Benford, S., Fraser, M., Greenhalgh, C., Schnädelbach, H., Lehn, D. V., Heath, C., Rowfarr, J., and Adams, M. Orchestrating a mixed reality performance. In *Computer Human Interaction* (2001), pp. 38–45.

[41] Krueger, R., and Casey, M. *A Practical Guide for Applied Research*. 3rd Edition Thousand Oaks, CA: Sage Publications, 2000, p. 219.

[42] Kuutti, K. Where are the ionians of user experience research? In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*, (New York,USA, 2010), NordiCHI '10, ACM, pp. 715–718.

[43] Lane, G. Urban tapestries: Wireless networking, public authoring and social knowledge. *Personal Ubiquitous Computing vol. 7*, (London, UK, July 2003), pp. 169–175.

[44] Christy, P., and Laurence, G. Gartner Says Worldwide Media Tablet Sales on Pace to Reach 19.5 Million Units in 2010, http://www.gartner.com/it/page.jsp?id=1452614 Last visited 26 January 2011

[45] Law, E. L.-C., Roto, V., Hassenzahl, M., Vermeeren, A. P., and Kort, J. Understanding, scoping and defining user experience: a survey approach. In *Proceedings of the 27th international conference on Human factors in computing systems* (New York, USA, 2009), CHI '09, ACM, pp. 719–728.

[46] Licoppe, C., and Guillot, R. ICTâs and the engineering of encounters: a case study of the development of a mobile game based on the geolocation of terminals. In *In Mobile Technologies of the City. Taylor and Francis. New York, Routledge* (2006).

[47] Ludford, P. J., Frankowski, D., Reily, K., Wilms, K. and Terveen, L. Because I Carry My Cell Phone Anyway: Effective Everyday Task Management. In *CHI 2006, Montreal, Canada* (April, 2006. ACM Press), pp. 889–898.

[48] Mehrabian, A. and Russell, J.A. *An approach to environmental psychology.* Cambridge, MA, USA; London, UK: MIT Press., 1974.

[49] Milgram, P., and Kishino, A. F. A taxonomy of mixed reality visual displays. vol. E77-D(12), IEICE Transactions on Information and Systems, pp. 1321–1329.

[50] Nieminen, M. P. *Process and Methods of User-Centered Concept Development.* Licentiate thesis, Helsinki University of Technology, Espoo, Finland, 2006.

[51] Norman, D. A. *Emotional design: Why We Love (or Hate) Everyday Things.* Published by Basic Books, 2004, p.268

[52] Norman, D. A. *Cognitive engineering.* in D. A. Norman and S. W. Draper, eds., User Centered System Design: New Perspectives on Human-Computer Interaction Lawrence Erlbaum Associates, Hillsdale, NJ., 1986, pp. 31–61

[53] Olsson, T., Ihamäki, P., Lagerstam, E., Ventä-Olkkonen, L., and Väänänen-Vainio-Mattila, K. User expectations for mobile mixed reality services: an initial user study. In *European Conference on Cognitive Ergonomics: Designing beyond the Product — Understanding Activity and User Experience in Ubiquitous Environments*, ECCE '09, VTT Technical Research Centre of Finland, 2009, pp. 19:1–19:9.

[54] Nieminen, M. P. and Mannonen, P. User-Centered Product Concept Development. *In: International Encyclopedia of Ergonomics and Human Factors. (2nd edition). New York 2005, Taylor & FrancisTaylor* (New York, 2006), pp. 1728–1732.

[55] Parasuraman, A. V. A. Z., and Berry, L. L. SERVQUAL: A Multiple-Item Scale for Measuring Customer Perceptions of Service Quality. *Journal of Retailing vol. 64* (1988), pp. 12–40.

[56] Tudor, B., Pettey, C. Gartner Says Worldwide Mobile Phone Sales Grew 35 Percent in Third Quarter 2010; Smartphone Sales Increased 96 Percent, http://www.gartner.com/it/page.jsp?id=1466313 Last visited 26 January 2011.

[57] Piekarski, W., and Thomas, B. ARQuake: the outdoor augmented reality gaming system. *Communications of The ACM vol. 45* (2002), pp. 36–38.

[58] Pirker, M. M., and Bernhaupt, R. Providing Feedback to UX Designers Using UX Evaluation Methods, Workshop Designer Experience: Exploring Ways to Design in Experience, CHI 2011, Vancouver, BC, Canada http://www.soberit.hut.fi/chi2011-dx/papers/Pirker.pdf

[59] Reilly, T. O., and Battelle, J. Web squared: Web 2.0 five years on. Technical Report, O'Reilly Media, Inc., 2009.

[60] Powell, R., and Single, H. Focus groups. *International Journal of Quality in Health care* vol. 8 no. (5) , 1996, pp. 499–504.

[61] Sandelowski, M. Combining Qualitative and Quantitative Sampling, Data Collection, and Analysis Techniques in Mixed-Method Studies. *Research in Nursing Health vol. 23*, no. 3, 2000, pp. 246–255.

[62] Stanney, K. Realizing the full potential of virtual reality: human factors issues that could stand in the way. In *Virtual Reality Annual International Symposium, 1995. Proceedings.* 1995, pp. 28–34.

[63] Tähti, M., Väinämö, S., Vanninen, V., and Isomursu, M. Catching Emotions Elicited by Mobile Services. In *Proc. Australian Conference on Computer-Human Interaction, Wollongong, Australia. (CD-ROM)* 2004.

[64] Turunen, M., Hakulinen, J., Melto, A., Heimonen, T., Laivo, T., and Hella, J. Suxes - user experience evaluation method for spoken and multimodal interaction. In *INTERSPEECH* (2009), pp. 2567–2570.

[65] Vaittinen, T., Kärkkäinen, T., and Olsson, T. A diary study on annotating locations with mixed reality information. In *Proceedings of the 9th International Conference on Mobile and Ubiquitous Multimedia* (New York, USA, 2010), MUM '10, ACM, pp. 21:1–21:10.

[66] Vallino, J. R. *Interactive Augmented Reality.* PhD thesis, University of Rochester, New York, 1998.

[67] van Kleef, N., Noltes, J., and van der Spoel, S. Success factors for Augmented Reality Business Models. Study Tour Pixel 2010 - University of Twente, July 2010. http://www.interactief.utwente.nl/studiereis/pixel/files/indepth/KleefSpoelNoltes.pdf

[68] Vredenburg, K., Mao, J.-Y., Smith, P. W., and Carey, T. A survey of user-centered design practice. In *Proceedings of the SIGCHI conference on Human factors in computing systems: Changing our world, changing ourselves* (New York, USA, 2002), CHI '02, ACM, pp. 471–478.

[69] Wilson, J., and Rosenberg, D. Rapid Prototyping for User Interface Design. In *In Handbook of Human-Computer Interaction* Elsevier Science Publishers, 1988, pp. 859–875.

Appendix A

UCD Empirical Study

A.1 Focus Group Background Questionnaire

Please rate each of them in the scale from 1(strongly disagree) to 5 (strongly agree)

1. I consider technology plays important role in my daily routine.
2. I use Face book or other online social networks for getting updates and sharing information.
3. I find it useful that my friends know my location and what I am doing.
4. I won't mind to share information on blogs and websites to help people if my identity is kept anonymous.
5. I am interested in knowing about discounts/offers related to places to eat, shopping and travelling.
6. I find it difficult to look for information when I am visiting unknown cities or different countries due to language barrier.
7. I am ready to pay if someone can assist me when I am visiting a place that I have never been to.
8. I am very much concerned about from privacy and do not want to share anything with the strangers.
9. I am worried about my personal information spreading in the web and getting into the wrong hands.

10. I want to share information related to discounts and offers with my friends.

11. I consider rating and recommendations for visiting places to eat/shop/travel as important.

A.2 Focus Group Discussions

1. What do you think this technology/service is useful or not?

2. What do think about the benefits from this kind of technology/service?

3. How you t this technology/service in your life?

4. What are the main strengths of this technology/service in your point of view?

5. Are you interested in using this technology/service? if yes then why? if not then what is the reason?

6. If this technology/service is paid the Are you still willing to use it in your daily routine?

7. What do you think is there any risk of using such kind of Technology/Service?

8. What do you think about privacy issues related to this Technology/Service ?

9. Where you think this kind of technology/service will be mostly used?

10. Apart from the shown scenarios where would you like to you this technology/service?

11. Is their any other use of this technology/service in your daily routine?

12. Do you want to see something different then what is shown in the scenarios?

13. What are your suggestions on this service and its use?

A.3 Focus Group Post Questionnaire

Please rate each of them in the scale from 1(strongly disagree) to 5 (strongly agree)

1. Would help to ease out cognitive load(load on the human memory)
2. Would help me to become smart traveler
3. Would help me to become smart shopping customer
4. Would help me to become Eco-friendly by avoiding paper printed offer/discount pamphlets such as K Market,S Market and Lidl
5. Would help to gain more information about my surrounding environment
6. Would help to fulfill my needs of the daily routine
7. Would bring liveliness to my life by evoking memories and emotions
8. Would add value to existing mobile services
9. Will definitely use the service as shown in the focus group if it comes into existence

Appendix B

UX Evaluation Questionnaire

B.1 SUXES Background Questionnaire

1. Please enter your participation number
2. Please enter your Age
3. Gender - Male, Female
4. How often you use the following services or applications on your mobile phones:
   (a) Internet(3G,4G,WLAN)on
   Daily, Weekly, Monthly, Couple of times in a year, Never used
   (b) Mobile applications that you install by yourself like mobile gmail,widgets
   Daily, Weekly, Monthly, Couple of times in a year, Never used
   (c) Social networking sites like Facebook
   Daily, Weekly, Monthly, Couple of times in a year, Never used
   (d) Location based reminders (LBRs) or applications
   Daily, Weekly, Monthly, Couple of times in a year, Never used
   (e) Map services like OVI Maps, Google maps
   Daily, Weekly, Monthly, Couple of times in a year, Never used
   (f) Voip services like Skype, Fring or Nuimbuzz
   Daily, Weekly, Monthly, Couple of times in a year, Never used

B.2 SUXES Expectation Questionnaire

MMR stands for Mobile Mixed Reality. Please answer each of the below given statements from 1 to 7 scale. Every statement should be answered by

giving one value each for acceptable and desired level. (1 stands for Low and 7 means High)

1. MMR is an innovative technology
2. MMR helps me in connecting with other people
3. MMR is fascinating to use
4. MMR is stylish and gives me a style statement
5. MMR can be used at public places and acceptable by other people
6. MMR is simple to use
7. MMR is intuitive and easy
8. MMR is useful in daily routine life
9. MMR is fast to use
10. MMR makes different possibilities of interaction quite visible

B.3 SUXES Perception Questionnaire

MMR stands for Mobile Mixed Reality. Please answer each of the below given statements with a perception level from 1 to 7 scale. (1 stands for Low and 7 means High)

1. MMR is an innovative technology
2. MMR helps me in connecting with other people
3. MMR is fascinating to use
4. MMR is stylish and gives me a style statement
5. MMR can be used at public places and acceptable by other people
6. MMR is simple to use
7. MMR is intuitive and easy
8. MMR is useful in daily routine life
9. MMR is fast to use
10. MMR makes different possibilities of interaction quite visible

B.4 AttrakDiff Questionnaire

Hedonic Quality Identification(HQI)

1. Stylish - Tacky
2. Predictable - Unpredictable
3. Cheap - Premium
4. Alienating - Integrating
5. Un-presentable - Presentable
6. Rejecting - Inviting
7. Unimaginative-Creative
8. Good - Bad
9. Brings me closer to people - Separates me from people

Hedonic Quality Stimulation(HQS)

1. Confusing - Clearly Structured
2. Repelling - Appealing
3. Bold - Cautious
4. Innovative - Conservative
5. Dull - Captivating
6. Undemanding - Challenging
7. Motivating - Discouraging
8. Novel - Ordinary
9. Unruly - Manageable

Pragmatic Quality(PQ)

1. Human - Technical
2. Isolating - Connective
3. Pleasant - Unpleasant
4. Inventive - Conventional
5. Simple - Complicated
6. Professional - Unprofessional
7. Ugly - Attractive
8. Practical - Impractical
9. Likeable - Disagreeable
10. Cumbersome - Straightforward