Gestural Interfaces for Maternal Healthcare: A Case Study of Rural Assam, North-East India

Thesis
submitted in fulfilment of the requirements
of the degree of

DOCTOR OF PHILOSOPHY

by

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April 2016

CERTIFICATE

This is to certify that the thesis entitled "**Gestural Interfaces for Maternal Healthcare: A Case Study of Rural Assam, North-East India**" submitted by Mr. Keyur Sorathia to the Indian Institute of Technology Guwahati, for the award of the degree of Doctor of Philosophy in Design is a record of bonafide research work carried out by him under my supervision and guidance. The thesis work, in my opinion, has reached the requisite standard fulfilling the requirement for the degree of Doctor of Philosophy. The results contained in this thesis have not been submitted in part or full to any other University or Institute for award of any degree or diploma.

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STATEMENT

I do hereby declare that the matter embodied in this thesis is the result of investigations carried out by me in the Department of Design, Indian Institute of Technology Guwahati, Guwahati, Assam, India.

In keeping with the general practice of reporting scientific observations, due acknowledgements have been made wherever the work described is based on the findings of other investigators.

(Keyur Sorathia)

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Abstract

An estimated 358,000 maternal deaths have occurred worldwide in 2008, out of which 99% of maternal deaths have occurred in developing countries. In this, India had contributed the highest with 63,000 maternal deaths during that year. It is further disturbing to note that the state of Assam is having highest Maternal Mortality Ratio (MMR) of 346 in the country. This is far above an average of 254. This demands an immediate need to intervene and find solutions to overcome maternal health challenges faced across the country. Information Communication Technologies (ICTs), often supported through mobile phone interventions demonstrate potential to become enabler of social development and overall growth. However it faces limitations of smaller screen sizes, in-appropriate technology platform, interaction modalities and poor usability for its successful acceptance among targeted user groups. One potential direction to overcome such problems is to use novel interaction mediums and modalities incorporating natural user interfaces adapted from human-human communication. Body-gestures are integral part of everyday communication that support naturalness in human communication. However, research on effective gesture based ICT interventions is still in infancy stage. Acceptance and effectiveness of such methods of interactions across low literate users of resource scarce regions has not been sufficiently explored. This research therefore, investigates the acceptance of gestural interfaces and effectiveness of body-gestures as interaction modality across low literate users of resource scarce regions. A case study with an aim to promote safe maternal health practices and educate pregnant women (PW) of rural Assam in India has been undertaken for this research.

This research outlines the outcome of four years of field based studies in the development and testing of an ICT enabled gesture based interactive system used in the domain of maternal healthcare amongst low literate PW in rural villages of Assam. The research studies are conducted amongst selected rural areas in Assam where user needs, problems, behaviors, information gaps, socio-cultural issues and technology literacy are studied, analyzed and interpreted. It resulted in highlighting the need of educating rural PW; the importance of role of Accredited Social Health Activists (ASHAs) and issues of gender prevalence in successful implementation of ICT systems. The study also presents three experiments aimed to generate authentic maternal healthcare contents, understand communication patterns to deliver sensitive maternal healthcare information and create user preferred body-gestures for generating suitable system design elements. The thesis demonstrates the design, development and deployment of the proposed gesture-based experiment called *Chetna*, a gesture enabled TV based audio-visual information system aimed to educate rural PW. Further, it reports the findings from 4 months of pilot study conducted at two different locations in rural Assam. The results show acceptance of gestural interface among rural PW and indicative results of learnability of body-gestures as interaction modality. It also reports significant learning of few individual body-gestures over 3 subsequent system interactions. It portrays gesture expressivity, posture variation, computer supported co-operative healthcare, persona usage, icons design and layout and instructional navigation as important factors influencing the acceptance of gesture-based GUI and decrease in performance of gesture errors. Reflections of on-field realities in form of infrastructural limitations, socio-cultural challenges and foreign researchers are also presented and discussed in details. The research findings resulted in suggesting a set of design guidelines for gesture based ICT enabled systems including – (i) posture inclusive design for body-mediated gestures (ii) gestures with flexible range of motion and tolerance in speed (iii) gesture interactive tutorials (iv) utilization of familiar persona (v) clear, continuous and consistent instructions and (v) designing with cultural and contextual limitations.

Finally, the thesis is concluded along with future research directions and a reflective note of the researcher.

Acknowledgements

I owe my gratitude to a number of people without whom this thesis would not have been possible. I would first like to express my sincere thanks to my supervisor Professor Ravi Mokashi Punekar for his guidance, encouragement, patience and support during the entire course of my thesis work. His technical expertise and his innovative ideas in the philosophy of research backed by his trenchant insight have always inspired me. I have been fortunate enough to have him as my professional guide. His calming influence and attitude has made me realize the importance of being focused, both at professional as well as personal fronts and this has induced deep stability in me.

Special acknowledgement is due to Professor(s) A. K. Das, S. B. Nair and S. R. M Prasanna for serving on my supervisory committee and providing their valuable inputs that were helpful in improving the thesis. I truly appreciate all of their time and assistance as I navigated through this process! I owe great thanks to the entire faculty colleagues and staff of Department of Design, IIT Guwahati. In particular, I would like to appreciate the research grant DES/P/KS/02 received as a Principal Investigator of this project. The project is funded by the IBM Research Labs India.

I also thank my friends Saurabh Srivastava and Jitumoni Baishya, students Mannu Amrit and Minal Jain, my research staffs Fabin Rasheed, Muckti Arora and Swastika Bhuyan for the help and support rendered during the experimental times. My family has been the bedrock, which has facilitated the growth of my career, providing me with the much required support to balance my professional and personal life. I would especially like to express my gratitude to mom, dad and my sister for their unconditional love and trust. They have been extremely supportive throughout my career and life. My parents in-law, supported me in countless ways, for which I am eternally grateful. My PhD experience was undoubtedly aided by my colleagues who provided support, conversation, encouragement and most importantly coffee drinking partners: who are too numerous to name. Without you this work would not be here today.

Most importantly, my deepest appreciation goes to the person without whom this last four years of my life would not have been so joyous, my wife, Poly. She has been my benign critic and biggest confidant. I cannot thank her enough for being always there motivating and inspiring me pushing me to look at the good sides of things. It's a challenge to write the PhD thesis when you are already working as a full time faculty, multi-tasking other research work and commitments. She unconditionally supported every phase of it and graciously even took time to read the draft, giving her critical inputs in the write up. I took the liberty to write most of the PhD chapters in the beautiful Prague, and Delft, visiting her during her post-doctoral research during the summer and winter vacation.

Bruno, our pet Labrador, is the most integral part of our small family multiplying our happiness. He has been instrumental in helping both me and Poly unwind during our PhD days. And now it's my turn to acknowledge the big boy.

Last, but the most important one - I would also like to thank all the pregnant women, health workers and health experts for supporting in the complete study. Without their support, this thesis would not have been possible.

Finally, I thank God for this enriching journey.

Keyur Sorathia

Contents

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List of Abbreviations

ANC	Antenatal Care
AR	Augmented Reality
ASHA	Accredited Social Health Activist
CHC	Community Health Center
CHW	Community Health Workers
DVD	Digital Video Disk
EAG	Empowered Action Group
FH	Food Habits
FHV	Female Health Volunteers
GB	Giga Byte
GHz	Giga Hertz
GOI	Government of India
GUI	Graphical User Interface
HB	Hemoglobin
HCI	Human Computer Interaction
HCI4D	Human Computer Interaction for Development
HMM	Hidden Markov Model
ICT	Information Communication Technology
ICTD	Information Communication Technology for Development
IT	Information Technology
MDG	Millennium Development Goals
MMR	Maternal Mortality Ratio
MMRate	Maternal Mortality Rate
mPHC	Mini Primary Health Center
NGO	Non-Governmental Organizations

NRHM	National Rural Health Mission
PHC	Primary Health Center
PPTCT	Prevention of Parent to Child Transmission
PW	Pregnant Women
RAM	Random Access Memory
RBS	Random Blood Sugar
S&R	Symptoms and Recommendations
SC	Sub Center
SDK	Software Development Kit
SMS	Short Message Service
T&C	Tests and Checkups
TAM3	Technology Acceptance Model 3
TT	Tetanus
TV	Television

Chapter 1

Introduction

1.1 Introduction to the context of this research

An estimated 358,000 maternal deaths have occurred worldwide in 2008, out of which 99% of maternal deaths have occurred in developing countries (WHO, 2010). India contributes the highest with 63,000 maternal deaths across the world. This is further extended with Assam having highest MMR of 346 in the country (WHO, 2010). Such numbers call for an immediate attention and action to empower maternal health conditions. Information awareness and access to relevant health information is often seen as an alternative for prevention (Pakenham-Walsh et al., 1997) in such conditions. ICT for information dissemination and awareness in resource scarce remote regions of developing countries has been investigated in various domains such as healthcare (Grover et. al., 2009; Medhi et al., 2011), agriculture (Ramamritham et al., 2006; Kumar, 2004; Patel et al., 2010), education (Singh et al., 2010) etc. and are often called as ICT for Development (ICT4D). Such explorations have often worked on mobile phones and computer enabled platforms due to its increased penetration in developing countries, especially India (TRAI, 2011). Despite its wider reach, limitations like small screen size, poor usability, low technology literacy, non-relevant modes of interaction hinders its acceptance and effectiveness among targeted user group (Sharma et al., 2014). Moreover, majority of users from rural areas in developing countries have low end mobile phones, without data connection and used as a shared resource among family members limiting the effective content delivery. Use of context relevant natural user interfaces is suggested to overcome such challenges and limitations (Best, 2010).

Body gestures are integral part of human-human communication. Humans utilize a broad range of gestures for everyday communications. Gestures in HCI have been implemented and investigated so far to limited users, often literate users with prior technology exposure and mostly in controlled lab environment in developed countries. Research on effective gesture based HCI is still in infancy stage and acceptance and effectiveness of such methods of interactions in resource scarce regions has not been sufficiently explored. This thesis aims to investigate acceptance and effectiveness of gestural interfaces in developing regions among low literate users. This is even more important to understand its acceptance when traditional ICTs bring new practices that challenge existing social and cultural structure of communities (Ramachandran, 2010).

1.2 Contributions

This thesis follows user centered approach to design-technology cycle, starting from need assessment through contextual inquiries, identifying contextually relevant body gestures and iterative design of health system to evaluation of its acceptance and effectiveness among rural PW of Assam, India.

Following are the specific contribution of this thesis.

1. Detailed user research of maternal health in rural Assam in India. Problems related to maternal healthcare, findings and analysis of socio-cultural issues and technology usage and understanding of PW (chapter 3)
2. Collection, extraction and elucidation of gestures generated through user generated gesture approach for operating identified computational functions (chapter 4)
3. Evidence that gestural user interfaces are accepted among rural PW of developing regions (chapter 7)

4. Evidence of increase in learnability of individual body-gestures over subsequent system interactions among rural PW of developing regions (chapter 7)
5. A series of guidelines for designing gestural interfaces for users that could potentially improve the chances of its acceptance in resource scarce developing regions (chapter 7)

1.3 Research motivation

India is a major contributor in world statistics of increasing MMR. A need to understand problems associated with higher maternal deaths, higher MMR and to overcome such problems has motivated this research. Technology interventions, especially through ICT enabled services are seen as major contributor for poverty alleviation and to achieve Millennium Development Goals (MDGs). It has demonstrated a potential to reach to wider section and strata of society without considering geographical barriers, which has encouraged me for pursuing it for empowering PW of resource scarce regions. It is of significant interest to learn about contextually appropriate technologies that help eliminate challenging barriers of technology literacy and help overcome critical problems. This calls for exploration and investigation of novel technologies and related interfaces. One of the most promising approaches so far is to use body gestures as medium of interaction. However, not many studies are reported in the literature where gestural interfaces have been investigated in developing countries, especially with low literature users from resource scarce regions. This indicates a dire need to clearly demonstrate whether gestural interfaces will prove effective in finding acceptance among rural PW. There is also a need to evaluate the learnability of body gestures as input modality to interact with digital interfaces among low literate users. It is also of a great significance to learn about the challenges of on-field research and reality when new interventions are put forward across non-technology savvy users.

1.4 Thesis organization

The thesis report is laid out into following chapters. Chapter 1, **Introduction** introduces the theme and context of the thesis report. It starts with describing the context of maternal healthcare in India, statistics of MMR in India, importance of intervening in maternal healthcare domain. This is followed by a quick overview of ICT supported interventions, its limitations and significance of investigating gestural interfaces among resource scarce regions (section 1.1). Research motivation is explained in section 1.2. Further, it presents the contribution in terms of findings of contextual inquiry, user generated gestures for computational functions, acceptance of body-gestures as suitable medium among rural PW and design guidelines in this research work to the existing body of knowledge in section 1.3. At last, section 1.4 details out the structure of this thesis.

Chapter 2, **A review and analysis of existing literature** details out on the existing body of knowledge and is further divided into 5 major sections. Section 2.1 introduces the domain of maternal healthcare where definitions of terms associated with maternal healthcare are reported followed by important indicators of worldwide and India specific maternal health scenario, government support health schemes and details of chosen study context of Assam in India. Section 2.2 - *Information communication technologies (ICTs)* introduces itself with multiple perspectives on ICTs followed by existing interventions in different computing and social domains. It further discusses the limitations, challenges and opportunity gaps in section 2.2.3. Section 2.3 – *Gesture based interaction* describes the importance of body-gestures in everyday communication followed by various definitions proposed by different authors. Gesture classifications and recognition technologies in the domain of HCI are elaborated in section 2.3.3. Section 2.3.4 presents extensive literature on gestural interfaces for healthcare, disability improvement, manipulation of television (TV) and computer interfaces, games and virtual reality interfaces. Section 2.4 - *ICT interventions in maternal healthcare* presents existing case studies of ICTs promoting healthy pregnancy followed by the discussions on their contexts, users, effectiveness, advantages, disadvantages and challenges. Section 2.5 - *Critical appraisal of literature review* discusses the potential research gap for above all 4 sections to demonstrate the need to investigate the domain of gestural interfaces in rural healthcare to further frame *Research hypothesis* (section 2.6) and *Aim and objectives* (section 2.7).

Chapter 3, **Planning and Methodology for Gathering System Design Elements of Gesture-based Experiment** presents 4 design research experiments conducted to identify suitable design elements for the proposal of gesture enabled ICT system. Section 3.1 reports on the contextual inquiry with description of the aims and objectives, study participants, procedure and data collection methods. This is followed by 4 major findings of contextual inquiry: (a) need for imparting appropriate maternal health information, (b) high dependence on ASHAs, (c) gender issues in social system and (d) familiarity and acceptance of TV platform. These findings form a basis to propose an interactive information system, which is elaborated in further sections 3.2, 3.3 and 3.4.

Section 3.2 – *Creation of maternal healthcare contents* presents a focus group study with health experts to create suitable maternal healthcare contents of (a) symptoms and recommendation (S&R), (b) tests and checkups (T&C) and (c) food habits (FH). Section 3.3 – *Study of appropriate method of health information communication* presents finding of the focus group study conducted ASHAs and PW of rural Assam. The findings presented instructional method for information communication, which is discussed in section 3.3.2. Section 3.4, *Study of investigating suitable body-gestures* presents the participatory design method employed to generate suitable body-gestures. The chapter starts with providing an overview of existing participatory approaches to design body-gestures in section 3.4.1. This is followed by detailed explanation of user generated gesture study in section 3.4.2, where detailed methods and findings of 3 stages – (a) defining computational functions (b) identifying logical gestures and (c) extracting suitable gesture are elaborated. Section 3.4.3 presents a graphical representation of finalized gestures and association with their computational functions. This is followed by section 3.4.4, which provides a brief overview on existing gesture recognition technologies and proposes to use a technology platform of Microsoft Kinect™ for accurate gesture detection. The chapter is finally summarized in section 3.4.5. Overall, chapter 3 presents the raw materials needed to design the proposed gesture-based experiment.

Chapter 4, **The development of gesture-based GUI** cleverly merges the design components identified in chapter 3 to propose a gesture enabled TV based maternal health information system called *Chetna.* It starts with section 4.1, where overall aims, objectives, system descriptions and components of *Chetna* are briefly explained. Section 4.2 presents the information structure of maternal healthcare contents to communicate to the PW. Overall design of graphical representation of *Chetna*, contextually appropriate interface background, persona of ASHA and PW and grid design of the GUI is elaborated in section 4.3. This is followed by brief description of the final list of gestures and associated computational functions of *Chetna* in section 4.4. A detailed description of protocol design for system interaction and navigation is presented in section 4.5, where system information architecture and step-by-step user authentication and interaction process is explained. System implementation of *Chetna* is explained in section 4.6, where proposed gesture recognition technology setup of Microsoft Kinect™, database generation through MySQL and 3D animation software of Maya are presented. The last section of this chapter, section 4.7 summarizes the chapter and further proposes a set of research questions in order to validate the hypothesis.

Chapter 5, **Field based experiments investigating the gesture-based GUI** presents the details of field trials conducted to investigate the research questions. It briefly presents the objectives in section 5.1 followed by detailed description of two chosen locations of rural Assam in 5.2. Detailed methodology adopted for validation study – participants, procedure, data collection methods and materials and apparatus are elaborated in section 5.3, 5.4, 5.5 and 5.6 respectively.

Chapter 6, **Results and discussions** presents and further discusses the findings identified from the field trials. It starts with system usage metrics where metrics related to the total number of participants, total viewed information and total performed body-gestures are presented. The system usage metrics are presented in section 6.1. This is followed by section 6.2 where detailed analysis on system acceptance metrics, participants' feedback and qualitative findings identified through observations are presented. Section 6.3 presents gesture metrics to further elaborate and validate the findings on learnability of body-gestures corresponding to the number of visits and types of gestures. The findings are discussed for an overall gesture learnability as well as learnability of individual gestures. Insights and inferences of the observation are also discussed in this section. This is followed by section 6.4 where subjective findings of field trials are reported and discussed. This section discusses the importance of using socially relevant design elements such as virtual agent of ASHA as persona and gender prevalence; importance of instructional navigation and placements of icons in GUI; variations of gesture performance – expressivity, postures and speed; participatory interaction of *Chetna* and technology limitations. It also discusses the limitations and challenges of the field trails – infrastructural limitations, socio-cultural challenges and discusses the research perspective for on-field studies. This is followed by presenting 6 design guidelines for designing gestural interfaces for rural healthcare drawn from the key findings.

Chapter 7 – **Summary** provides a brief overview of the thesis whereas chapter 8 - **Conclusion** is the final chapter, where concluding remarks on the experiments, field study and hypothesis are presented. This is followed by reflections and viewpoints of the researcher about the research work. In last section, the thesis debates on future research directions for gestural interfaces among rural users of resource scarce regions.

Chapter 2

A Review and Analysis of Existing Literature

This chapter is an intersection of existing literature on three focus areas of this research: maternal healthcare (section 2.1), technology-supported interventions especially through ICTs (section 2.2) and gesture-based interfaces in ICT interventions (section 2.3). Figure 1 demonstrates a visual representation of the intersection for this research.

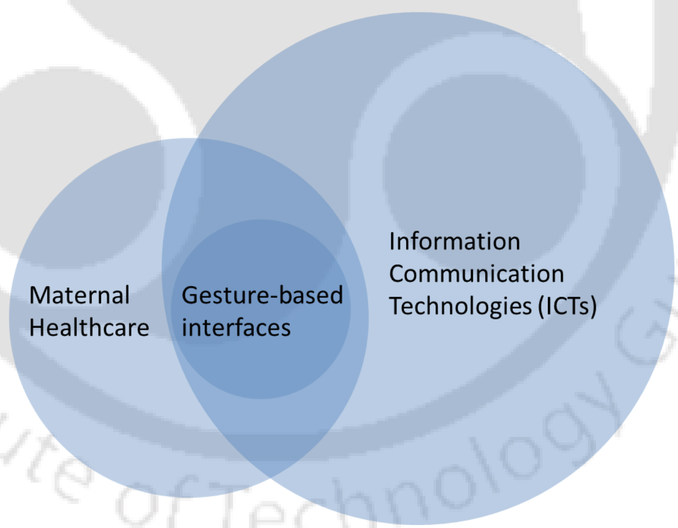

Figure 1: A figure demonstrating intersection of three focus areas for literature review: ICT, gesture-based interfaces and maternal healthcare

This chapter starts with providing in-depth understanding of maternal healthcare –worldwide and India in order to set a base for maternal healthcare as a case example for this research. Terminologies associated with maternal healthcare, its increasing penetration in worldwide and Indian scenario and existing government initiatives to curb maternal healthcare are explained in details. This is followed by various examples of ICT supported healthcare, education, agriculture etc. interventions to showcase its potential as a key alternative to solve critical societal problems, especially in developing regions (section 2.2). Despite the potential demonstrated by ICT interventions in developing regions, it still possesses few challenges. Section 2.2.3 presents these limitations and challenges experienced by traditional ICTs, especially interventions supported through mobile phones. It further justifies the need to explore natural interaction modalities, with body-gestures being the most promising one to overcome the existing challenges and increase acceptance of ICT interventions. This section forms the basis of our research direction with gesture interfaces and gestures as interaction modality being core focus of this research. To further strengthen the research direction and analyze future scope of research, an in-depth reporting of existing literature in gesture-based interactions is presented in section 2.3. This section includes gesture definition and categories in HCI, recognition technologies, exploration of gestural interfaces in healthcare, education, gaming etc., and methodologies of designing suitable gestures. Finally, section 2.5 critically reviews and analyzes the complete literature examples presented in three sections (e.g. 2.1, 2.2 and 2.3) to form the research hypothesis and aims and objectives presented in section 2.7 and 2.8 respectively.

2.1 Understanding maternal healthcare

Maternal death of a woman during pregnancy, at delivery, or soon after delivery is a tragedy for her family and for society as a whole. The mortality rates due to preventable tragedies in the developing world are significantly high with 99% maternal deaths represented by developing nations (WHO, 2010). There is an undeniable need to provide reliable healthcare services to communities and to those responsible for providing care in these places.

The following section deals with often used comprehensive definition of the terms associated with maternal healthcare followed by a brief worldwide and India specific overview on maternal healthcare.

2.1.1 Definition of the terms associated with maternal healthcare

Maternal deaths, MMR and MMRate are often used terms in literature to explain maternal healthcare conditions worldwide. International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, 1992 (ICD-10) and World Health Organization (WHO) defines maternal death as,

> *"The death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental cause"*

The maternal death identification is done based on direct or indirect relationship with pregnancy related complications. Direct deaths are those resulting from complications of the pregnant state (pregnancy, delivery and postpartum) from intervention, omission, incorrect treatment or chain of the events resulting from any of the above. Indirect death relates to previous disease, disease that developed during pregnancy and by physiological effect of pregnancy. Definition of MMR (WHO, 2010) is,

> *"The MMR is defined as the number of maternal deaths in a population divided by the number of live births. Basically, it depicts the risk of maternal deaths relative to number of live births"*

Definition of MMRate (WHO, 2010) is,

> *"MMRate is defined as number of maternal deaths in a population divided by the number of women of reproductive age"*

MMRate reflects the risk of maternal death per live birth as well as level of fertility in the population.

2.1.2 Maternal healthcare indicators

Following sections present a world and India overview of maternal health indicators.

2.1.2.1 An overview of maternal healthcare indicators across the globe

It can be noted that despite decrease in maternal deaths across the world (546,000 in 1990 to 358,000 in 2008) and 34% decline in MMR (WHO, 2010), improvisation of maternal health scenario across the world remains a major concern. The fifth MDG aims to achieve 5.5% annual decline till 2015.

As per WHO (2010) report, an estimated 358,000 maternal deaths have occurred worldwide in 2008, out of which 99% of maternal deaths have occurred in developing countries. Sub-Saharan Africa and South Asia accounted for 87% (313,000) of global maternal deaths. Other countries such as Afghanistan, Bangladesh, Ethiopia, India, Indonesia, Kenya, Nigeria, Pakistan, Sudan, and the United Republic of Tanzania, comprised 65% of all maternal deaths (WHO, 2010). The MMR was also found higher in developing regions in contrast of developed regions. Sub-Saharan Africa, Afghanistan, Lao People's Democratic Republic, Nepal, Timor-Leste, Bangladesh, Haiti, and Cambodia have 640, 1400, 580, 380, 370, 340, 300 and 290 maternal deaths per 100,000 live birth respectively. As shown in figure 1, India contributes highest maternal deaths of 63,000 followed by Nigeria (50,000), the Democratic Republic of the Congo (19,000), Afghanistan (18,000), Ethiopia (14,000), Pakistan (14,000), the United Republic of Tanzania (14,000), Bangladesh (12,000), Indonesia (10,000), Sudan (9,700), and Kenya (7,900). Indicators in figure 1 suggest an immediate need for interventions to curb MMR in developing countries such as India. It demands an immediate attention to relook at our existing policies and potential new alternatives to empower maternal healthcare.

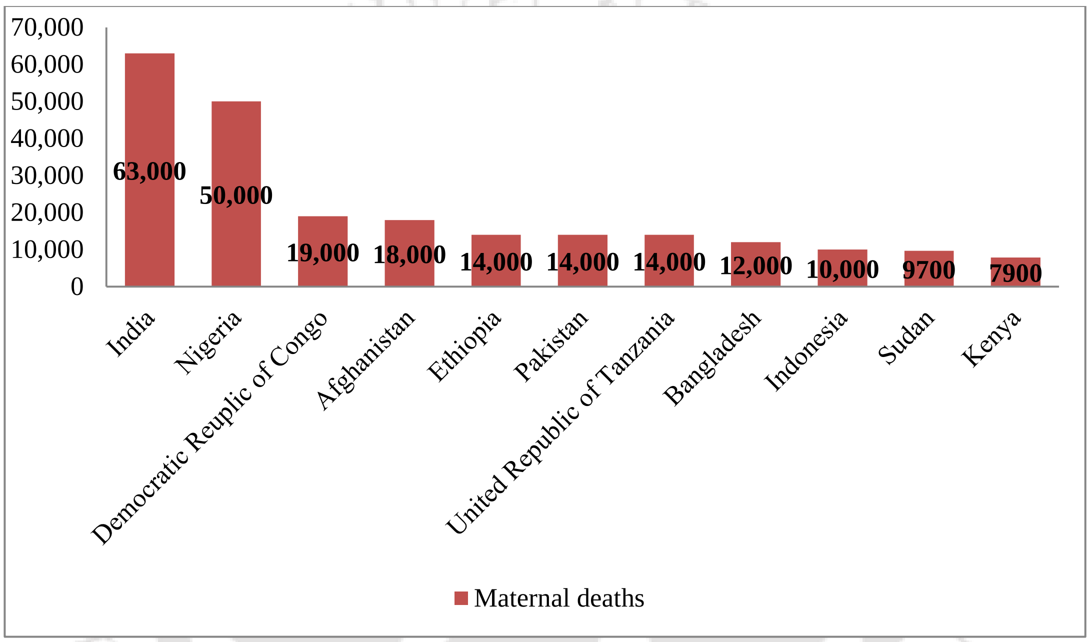

Figure 2: Statistics of countries with high maternal deaths. Source – WHO 2010 Report

2.1.2.2 An overview of maternal health indicators in India

Since the beginning of MDG, India has accounted for highest maternal death across the world. Despite its programmatic efforts and rapid economic growth over last decade, India's goal to lower MMR to less than 100 per 100,000 live births looks like a dream. WHO (2010) report suggests that India is making progress with 59% reduction in MMR since 1990, showcasing annual decrease rate of 4.9%. Despite the decline in maternal deaths, India continues to contribute the highest number of maternal deaths across the world, having 63,000 maternal deaths in 2008. India accounts for over a fifth of maternal deaths of the world (WHO, 2010) which is found poorer than many developing countries with similar or lower income per head. Indian states such as Assam, Orissa, Rajasthan and Uttar Pradesh/Uttarakhand have reported 390, 258, 318 and 359 MMR respectively in 2009 (Census of India, MMR report 2010-2012). These rates of MMR are unacceptably high and hinder national potential to improve maternal healthcare status and overall life expectancy at faster rate.

2.1.2.3 Government supported maternal healthcare initiatives in India

A number of welfare programs have been introduced by Government of India (GOI) in order to improve reproductive health of mother and to reduce MMR in the country. India has recorded impressive infrastructure development to expand the public health sector to 144,988 Sub Centers (SCs), 22,669 Primary Health Centers (PHCs) and 3910 Community Health Centers (CHCs) (Dhingra et al., 2011). CHCs, PHCs and SCs cater to patients of district, block and village areas respectively. SCs and PHCs are often accessed to avail basic health services and government supported benefits whereas CHCs provide benefits for patients demanding advance medical facilities. With an aim to improve overall health conditions in India, a major initiative of setting a national and state level health body called National Rural Health Mission (NRHM) was setup in 2005. CHCs, PHCs and SCs were later transferred under the state body of NRHM which further reports to the national body of NRHM in order to define new health policies and schemes. The program aims to bring health and family welfare programs under one umbrella to improve the health of rural people and initiate new schemes to reduce child and maternal mortality, along with other healthcare initiatives. Healthcare services provided to mother under NRHM includes three main stages: antenatal care (ANC), intra-natal care and postnatal care. ANC services are provided for 3 times during each trimester of pregnancy. During these ANC services, general examination of PW such as weight, height, blood group, blood pressure, anemia, abdominal examination, iron and folic acid supplements, tetanus (TT) injections, urine tests, albumin tests, ultrasound etc. are covered. PW enrolled under NRHM are further provided with monetary benefits for institutional deliveries.

Female Health Volunteers (FHV) were also associated with NRHM, which were later named ASHA. ASHA is often a volunteer identified from a local community to conduct frequent village visits, identify PW in a local community and help them to receive adequate ANC services through community mobilization efforts. They act as a social mediator enabling an effective bridge between the community and government efforts to promote health benefits, health schemes, institutional deliveries, immunizations and family planning for local people.

Another health initiative, the Janani Suraksha Yojana (Women's Protection Scheme) (Lim et al., 2010), developed under NRHM aimed at improving delivery and post-delivery care for poor PW and promoting institutional delivery in rural areas, which offers cash incentives for nutrition and transport to institutional deliveries for women undergoing delivery in government institutions and selected private institutions. The scheme aims to demote home delivery practices in rural areas whereas promoting to avail institutional delivery among PW. Similarly, various state specific programs such as the ASHA radio program and Boat Clinic services (Sharma, 2009) attempted to upgrade the standard of life of the rural people with respect to health and hygiene and particularly promoting the healthy environment for mother and child.

Despite introduction to infrastructural and policy level developments, utilization of these services, especially ANC are found very less (Navaneetham and Dharmalingam, 2002; Agarwal et al., 2007; Vora et al., 2009). This is mainly due to lack of information, willingness to visit hospitals and reliability on traditional methods. Progress in the improvement of maternal health is found low and considered in a developing stage. MMR is still unacceptably high and indicates to fall short of attaining many of the targets of MDGs. There is an undeniable need to provide acceptable, effective and influential alternative to overcome this challenge.

The main objective of this research is to understand and improve the maternal health and aim towards social innovation. The focus is to overcome challenges faced and attempt to provide alternatives that can complement existing initiatives by the government supported programs to improve MMR. This thesis tries to understand the problems, needs and behaviors of people associated with maternal health in order to attempt an engaging, encouraging and influential alternative to empower maternal healthcare amongst people in today's technologically empowered society.

2.2 Information Communication Technologies (ICTs)

This section presents literature review and analysis of ICT supported interventions and gesture based interaction in Human Computer Interaction (HCI). It begins by introducing ICT, its growth in the past decade, an overview of existing literature on ICT for development for societal needs (e.g. healthcare, education, agriculture, e-governance etc.), where the importance and effectiveness of its reach and impact is portrayed. It also expands the views on limitation and challenges faced in ICT, especially with web and mobile enabled platforms for low literate users of developing regions.

The second section begins with an overview of body gestures in human-human communication followed by introducing gestures in HCI and computing interfaces, existing literature of gesture based HCI in different application domains, design guidelines and evaluating parameters. Finally, this chapter ends with a critical appraisal of existing literature establishing a need to investigate gestural interfaces among low literate users in resource scarce regions.

2.2.1 *ICTs – growth and penetration in India*

ICT explains the use of technology enabled interventions and tools to communicate information where methods, concepts and applications associated are constantly evolving on a daily basis.

Blurton (1999) focuses on the use of technological resources for information communication and defines ICT as,

> *"Diverse set of technological tools and resources used to communicate, and to create, disseminate, store and manage information"*

Similarly, Batchelor (2002), Chapman and Slaymaker (2009) and Rao (2007) elaborates on ICTs as,

> "*ICTs essentially facilitate the creation, management, storage, retrieval, and dissemination of any relevant data, knowledge, and information that may have been already processed and adapted*"

It primarily focuses on communication technologies which include internet, mobile phones, wireless networks, TV, satellite systems and other communication platforms to disseminate information or knowledge through associated applications and services. Castells (1996) and Friedrichs (1989) have labelled the current and forth coming ICT dependent developments as the "Information revolution" or the "Information age".

The growth seen in ICT over the last decade has been extraordinary, particularly in emerging economies. Conference Board Report (2008) suggests incredible growth with 24% and 8% increase in ICT investment in advanced and emerging economies respectively. The Telecom Regulatory Authority of India (TRAI) (2011) report indicates that in India new 227.27 million mobile phone subscribers have been added to reach its total count at 811.59 million, registering a growth of 38.89%. Growth rate seen in telecom subscription is not limited to urban areas, but the penetration is observed to be higher in rural areas too. The growth rate of telecom subscribers in rural areas is higher at 40.64% as compared to 34.11% in urban areas. Similarly, internet penetration has increased to 35 million users accessing the internet on mobile phone and 19.67 million users through broadband and narrowband internet connectivity in India.

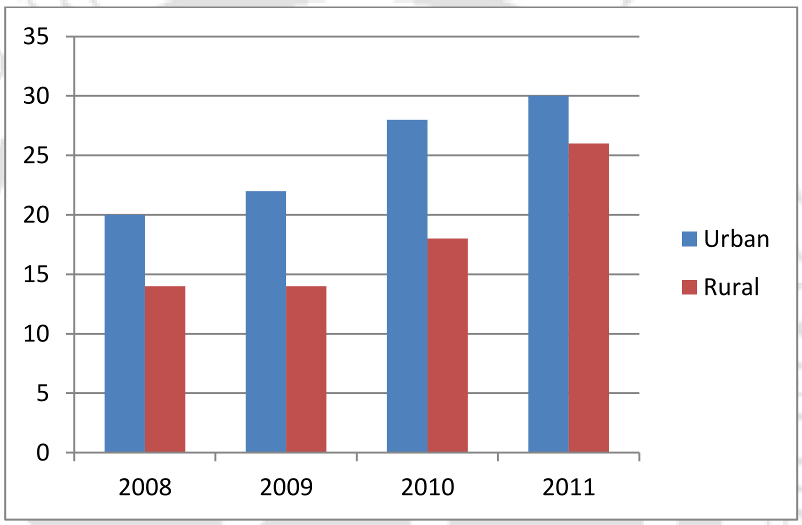

Figure 3: Percentage growth of mobile phone subscription in urban and rural India. Source – TRAI Report 2011

What is evident here is the reach of ICTs to wider audiences of urban as well as rural areas, thus becoming a powerful channel to deliver essential information and services. ICT enabled platforms help to avail improved services to larger populations. Penetration of ICT enabled platforms, increased numbers of internet users across India and possibilities of merging ICT enabled platforms and internet based application widens the scope and opportunity for experts to provide information services escaping the boundaries of low infrastructure, urban-rural divide and reach of remote areas. ICT enabled interventions in key development areas have been elaborated in further sections.

2.2.2 ICT enabled interventions for societal development

ICT enabled platforms are not limited to developed countries with literate users but have reached to marginalized users of resource scarce regions. Studies have been done to cater to low literate, low socio-economic and disadvantageous communities and users of developing regions. Attempts have been made to address challenges faced by traditionally underdeveloped areas such as healthcare (Grover et al., 2009), agriculture (Ramamritham et al., 2006; Kumar, 2004; Patel et al., 2010) and governance (Mudliar et al., 2012).

This section demonstrates a variety of ways in which ICT is applied to broaden its utility, acceptance and explorations in various sectors in India and amongst other developing countries. ICT enabled services through mobile and computer platforms have been used for remote mentoring and monitoring. Ramamritham et al., (2006) build a web based multilingual multimedia community platform to support farmers remotely. The proposed system called *aAQUA* allowed farmers of Maharashtra, India to post photographs of damaged crops on a community forum where rectifications were remotely suggested by agriculture experts. Similar services by Kumar (2004) and Patel et al., (2010) are designed to remotely connect peer farmers and experts in order to support agriculture practices in India. It not only supports expert opinions but also allows experienced farmers to share their experiences and knowledge with peer groups. *Sehatsaathi* (2005) is a rural telemedicine system to provide primary health services remotely through an interactive kiosk. It brings patients and experts together to answer questions from remote locations. Similarly, ICT enabled health initiative to support remote services for child care vaccination, deworming and disease prevention and data transmission to remotely support technicians through web services are designed by Vishnevskaya

RostroPovich Foundation (Tsertsvadze et al., 2008) and Voxiva (Prahlad, 2005) respectively. These services build networks and partnerships to empower people, become a thread to bring users and experts together, allow them to share, discuss and find a way to solve their problems. Important suggestions and tips are made available to underserved population through remote services by domain experts. Expert suggestions are made available through tips provided to patients, teacher trainings, students and farmers.

Vital information, marketing and financial services have been explored by building information networks to increase the market reach for small and medium size enterprises, facilitating the exchange of experience and information to provide job prospects and financial sustainability through ICT enabled services. Alampay et al., (2009) and Mas and Radcliffe (2010) demonstrate the impact of ICT in financial exchanges, where mobile phones are used to exchange and transfer money and make payments in Philippines and Kenya respectively. ICTs positive impact on economic development has been presented by Konstadakopulos (2005), Donner (2006), Abraham (2007) and Jagun et al., (2008) where mobile phone enabled services have been used to uplift the fishing industry in Kerala, India, empower micro-entrepreneurs and small and medium enterprises through building information networks, support increased market outreach, market information and profitability in Vietnam, Kenya, Nigeria, and other African countries.

A requirement to provide information services to the rural population in developing countries have also been explored through information dissemination and awareness. Such services have been utilized for broadening educational opportunities, health services, agricultural support, community awareness programs, government supported policy and program initiatives and information exchange to name a few. Veeraraghavan et al., (2007) designed a mobile interface providing market information, demand and supply need and market prices to rural sugarcane cooperative in India. Leinonen et al., (2006) developed a *MobilED* server to empower a community information system called *AudioWiki*, where users can send a search term which will be communicated to users through a call and present information identified from *Mediawiki* of *MobilED* server. It was designed to be information system for people who do not have internet connectivity. Mudliar et al., (2012) developed a mobile and web enabled voice forum called *CGNet Swara* to promote citizen journalism in rural India. Users of this forum become reporters, record a message to report local problems and listen to messages others have recorded. Gandhi et al., (2007) designed a digital green platform that provided agricultural information on TV and Digital Video Disk (DVD) player. Contents in the form of videos were created through a participatory approach among farmers to generate local video database of human mediated instruction for information dissemination and training.

Training and empowerment have also proven effective through successful inclusion of digital technologies and ICTs (Mariscal et al., 2009; Walton et al., 2009; Chapple, 2006; Sullivan et al., 2007) for under privileged users from remote regions. Training and upliftment program have been inducted in support of Non-Governmental Organizations (NGO) and government organizations to impart knowledge and skills to expand employment opportunities, reduce social and economic gaps, increase productivity and competitiveness among users.

Overall, ICT portrays itself as an effective enabling tool for key development areas in developing countries and resource scarce regions across all section and strata of society. It demonstrates tremendous potential to become enabler for growth in critical domains of healthcare, education, agriculture, e-governance etc. to support a variety of systems such as information dissemination, awareness, training, upliftment, widened market reach, marketing, financial sustainability and many more. Due to broaden utility areas, acceptance, reach to remote regions and potential to create an impact, ICTs are seen as potential alternative for societal development in resource scarce regions.

2.2.3 Limitations and challenges of ICT enabled interventions

ICTs have shown tremendous potential to be integrated for poverty alleviation and social development programs across the developing world through information outreach, ease of access, increased capacity and motivation. Ideas leveraging ICT platforms are developed on computers or laptops, tele-centers and most often leveraging the use of mobile phones. Despite penetration of such platforms, especially of mobile phones in developing countries, many limitations and challenges are observed in its acceptance in developing nations. A consistent observation among the limitations is its usability (Heeks, 2008; Sambasivan et al., 2009; Medhi et al., 2008), technology illiteracy or lack of technical skills (Yadav et al., 2010; Richardson, 2006; Jere et al., 2013; Best, 2010), language barriers (Kumar et al., 2010), contextually inappropriate use of technology and non-relevant modes of interaction (Donaldson, 2009; Winschiers, 2006; Best, 2010). Moreover, a majority of users from rural areas in developing countries have low end mobile phones, without data connection and are observed to be used as a shared resource among family members limiting the effective content delivery (Sharma et al., 2014).

Attempts have been made to overcome above challenges and limitations. Emergence of user centric technologies have given rise to inclusion of natural interfaces in ICT for Development (ICTD), especially spoken languages and body gestures. Natural spoken languages have been incorporated through spoken web technology (Kumar et al., 2010), enabling dissemination of health information through speech input (Sherwani et al., 2007; Grover et al., 2009) and navigating across audio contents (Dhanesha et al, 2010; Plauche and Nallasamy, 2007). These interfaces have been investigated across under privileged users in developing countries. It allows users to interact with computer and mobile based applications by using natural spoken language, however there are challenges of multiple languages and dialect (Toyama, 2011; Kumar et al., 2010). Moreover, such technologies have not matured for accurate recognition yet, mainly causing difficulties in recognizing in crowded places (Plauche and Nallaswamy, 2007). Similarly touch enabled interfaces (e.g. touch screen kiosks, touchscreen based mobile phones etc.), are gaining momentum in developing regions, yet they can be challenging for new users who have to learn the new interface and an unfamiliar method of touch-based interactions (Sharma et al., 2014).

Another mode emphasizing on naturalness of interfaces is human body gestures. Humans are proficient at using gestures in everyday world. Body-gestures offer one of most natural medium of communication and remain consistent for common communication dialogs (as compare to speech) across geographical boundaries. Moreover, recent technological interventions such as Nintendo Wii™, Microsoft Kinect™ etc. have clearly shown accurate recognition of gestures for HCI systems. Despite the potential as an important contributor in HCI systems, very few HCI systems use gestures as a direct manipulation medium, especially in resource scarce regions. This thesis aims to build on an opportunity to use more natural user interface i.e. human body gestures in ICTD which has not been sufficiently explored in developing regions among marginalized user groups and offers scope for further investigation. This also supports research that suggests moving beyond traditional computers and mobile interfaces and propose novel interaction techniques in Human Computer Interaction for Development (HCI4D) (Best, 2010).

2.3 Gesture based interaction

This section presents literature review and analysis of worldwide research on gestural interfaces. A large body of literature is reviewed to understand the role of gestures in everyday communications, types of gestures, the role of gestures in HCI and related research experiments in order to gain an understanding of theoretical perspective of gestural interfaces.

This section starts with a brief overview on the role of gestures in everyday communication followed by various definitions and classifications of gestures widely accepted in HCI. Evolution of gesture detection methods, models and technology interventions are explained in *Recognition Technologies* (section 2.3.3.2) followed by existing explorations and analysis of gestural interfaces in health, education, games and other computing domains (section 2.3.4). The fundamentals of gestural interfaces, design guidelines and critical parameters to evaluate usability for body gestures are elaborated in *Design Guidelines for Gestural Interface* (section 2.3.3.3.7) and *Evaluating Parameters* (section 2.3.3.3.8) respectively.

2.3.1 Body-gestures as communication medium

Gestures play a very important role in human-human communication. Gestures serve as a communicative function in face-to-face communication and appear to be integral to the production and comprehension of language in face-to-face contexts. Humans unwittingly produce gestures either alone or along with speech to communicate different information and situations. Gestures are produced irrespective of listeners' presence (Rime, 1982) although it is produced more in a presence of a listener (Cohen, 1977; Cohen and Harrison, 1973). Body gestures are an integral part of communication when co-occurred with semantically parallel speech or during syntactically complex communication (McNeill, 1992). Listeners take into account the information conveyed by gestures, even when this information is not redundant to the information conveyed in speech (Cassel, 1998). They become even more critical while communicating to alien devices, especially due to non-familiarity of language and other communicating modalities. Broad range gestures are utilized in everyday communications. Gestures are the key component of human to human communication, hence demonstrate an ability to provide a quick and easy way to learn system interactions. The following section defines gestures from a perspective of HCI.

2.3.2 *Defining gestures in HCI*

It is important to understand what is being considered as gestures, especially when thinking about gesture as medium to interact with digital interfaces. There is no clear and widely accepted definition of gesture, hence a definition widely used in HCI literature is reported here.

Kurtenbach and Hulteen (1990) define gestures as,

"A gesture is a motion of the body that contains information"

Waving goodbye is a gesture. Pressing a key on a keyboard is not a gesture because of the motion of a finger on its way to hitting a key is neither observed nor significant. All that matters is which key was pressed.

Similar to Kurtenbach and Hulteen, McNeill (2008) defines gestures as,

"Movement that communicates information, intentionally or not"

Väänänen and Böhm (1993) add an observer's perspective to define gestures. They present gestures as,

"Body movements which are used to convey some kind of information from one person to another"

Hummels and Stappers (1998) define gesture as,

"A movement of one's body that convey meaning to oneself or to partner in communication"

They take the definition ahead by describing a partner being a human or a computer. They describe gestures as a large movement of any body part (e.g. body, face, hands and sometime tools). Gestures associated with objects where interactions with a surface of an object such as grasping objects are also considered to be gestures.

2.3.3 Gesture based interaction in HCI

As computers become integrated into everyday objects, often called ubiquitous and pervasive computing, effective and efficient use of interaction mediums becomes critical in controlling computer interfaces. It is recommended that users need to be able to interact naturally with computers the way face-to-face human-to-human interaction takes place (Jaimes and Sebe, 2007). Body gestures propose promising interaction medium enabling natural communication with computers and computing platforms.

Gesture-based interaction in traditional HCI typically consists of hand movements, body motion and facial expressions. Gestures are considered as a new interaction paradigm where the interface components are organized in the user's physical space (Kaplan, 2009) and a user directly manipulates interface components positioned around his body. The recent diffusion of advanced technologies, especially Nintendo Wii™ and Microsoft Kinect™ and the release of their proprietary Software Development Kits (SDKs) have made possible for implementing new forms of 3D user interfaces based on touchless gestures. It is possible to enhance interaction experiences with computers by building new forms of natural interfaces.

Gestures in HCI can be broadly divided into two phases i) touch enabled gestures and ii) touchless gestural interfaces. Touch enabled gestures are mainly seen in mobile phone related interfaces and interactive surfaces incorporating multi-touch gestures. However, the scope of this thesis is limited to touchless gestural interface employing human body-gestures that allow operation from a distance to operate digital interfaces. Touchless gestural interaction enables users to interact with digital devices using body movements and gestures. This is without the burden of physical contact with technology (e.g., data gloves, body markers, or remote controllers), expecting it to be more natural, spontaneous, intuitive, and pleasurable than other forms of interactions (Garzotto and Valoriani, 2013). The following sections provide an overview of widely used gesture classification in HCI followed by a classification based on gestural interface applications on various areas.

2.3.3.1 Gesture classifications in HCI

Gestures exist in isolation or involve external objects. A broad range of isolated and external object enabled gestures such as formal sign languages, universal gestures, wave, beckon, pointing at objects, touching or moving objects, changing objects shape, activating objects such as controls or handing objects to others etc. are performed in human-human communications. Gestures performed in a variety of ways are further formally classified in literature through various taxonomies. This section provides an overview of gesture categories specified in literature in HCI context.

Claude (1994) suggested gestures to be classified according to their functions. Following are the proposed classifications.

- *Semiotic:* those used to communicate meaningful information.
- *Ergotic:* those used to manipulate the physical world and create artifacts
- *Epistemic:* those used to learn from the environment through tactile or haptic exploration

A step further, Rime and Schiarature (1991) classified following categories of gestures to communicate with computers.

- *Symbolic gestures:* Symbolic gestures define a single meaning in each culture. An emblem of “OK” gesture is an example supporting symbolic gesture.
- *Deictic gestures:* Deictic gestures are often observed and experimented in HCI projects. They are gestures of pointing or directing the listeners’ attention to specific events or objects in the environment.

- *Iconic gestures:* Iconic gestures convey information about the size, shape or orientation of the object of discourse. When someone says "the object rolled like this", while moving their rolling hands and fingers in a similar style of rolling object, they demonstrate the category of iconic gestures.
- *Metaphoric gestures:* This category of gesture represents derived features of an object or action, such as drawing a rectangle to represent a frame or imitate writing on a paper. It is similar to iconic gestures, however it represents abstract concepts.
- *Pantomimic gestures:* These are gestures often used in showing the use of movement of some invisible tool or object in the speaker's hand. When someone says "The steering wheel was turned hard to the left", while imitating the actions of turning the wheel hard to the left, they are representing a pantomimic gesture.

Gestures which relate to the process of communication, especially with speech have also been classified as beat & cohesive gestures (McNeill, 1992) in literature. This is however, out of the scope of this thesis and hence not elaborated here.

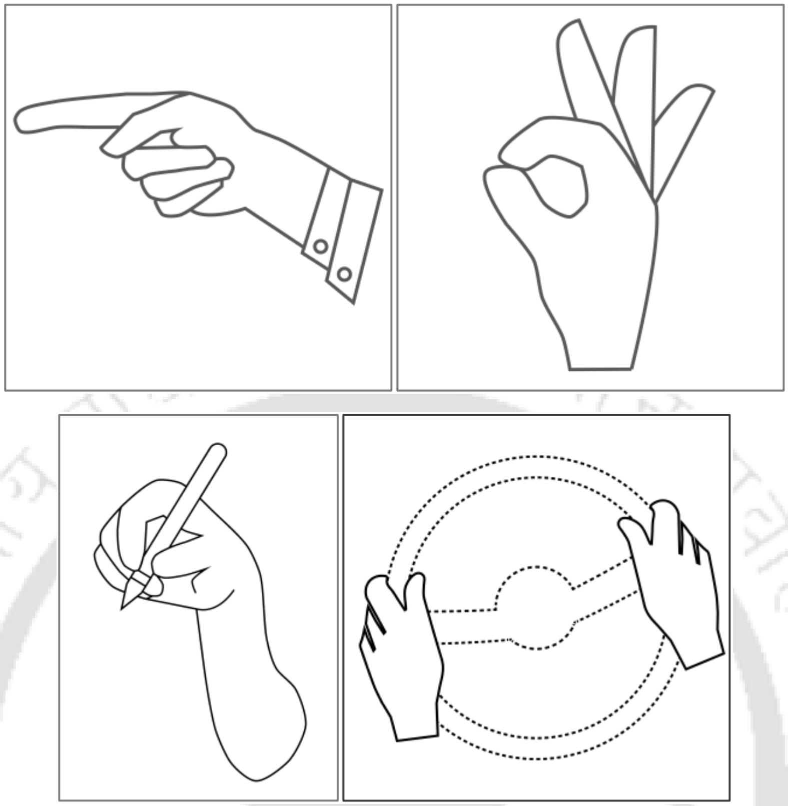

Figure 4: Gestures (left-to-right) of pointing (Deictic gesture), OK (Symbolic gesture), imitating writing (Metaphoric gesture) and turning the wheel (Pantomimic gesture)

2.3.3.2 Recognition technologies for gestural interfaces in HCI

Earlier interventions in gestural interfaces have focused on technological perspective with an aim for accurate gesture detection and recognition. Various camera enabled detection methodologies such as Hidden Markov Model (HMM) (Kobayashi and Haruyama, 1997), motion path based gesture recognition (Rahman et al, 2009) model and appearance based real time tracking approach to capture hand motion with camera (Wang et al., 2007), recognizing accelerometer based gesture added noise distorted signals through HMM (Mäntyjärvi et al., 2004), face pose recognition method using the pose appearance manifold (Kang and Ju, 2007) and tracking a moving body in a sequence of camera images by model adaption where model images and camera images of the user are used as quality measures (Lange et al., 2004) are explored. Similarly motion sensor attached approaches for gesture detection to track hand position and orientation have also been developed (Zimmerman et al., 1987; Kramer and Leifer, 1989; Sturman and Zeltzer, 1994). Past few years have seen advent of new commercially available technologies such as Nintendo Wii™ – an accelerometer and infrared sensor based object detection and Microsoft Kinect™ – a RGB camera and infrared sensor based body gesture motion tracking providing a strong commercial basis of accurate gesture detection. Nintendo Wii requires a Wiimote control that has accelerometer and infrared sensor for detecting movements of the remote control. Microsoft Kinect™ detects body positioning and movements through RGB camera and infrared sensors with the use of holding any remote control. These technologies have readily available SDKs for experiments and explorations, which makes them a preferable choice for gestural interfaces investigating non-technical parameters.

2.3.4 Existing explorations on gestural interfaces

Following sections elaborate on existing interventions of gestural interfaces on different technology platforms and research areas of various contexts. It also presents existing guidelines for designing gestural interfaces and reports evaluating and investigating parameters proposed in various research explorations.

2.3.4.1 Gestures for manipulation and augmentation to computer applications

The first gesture based interaction was investigated by Sutherland (1964) in his PhD work who demonstrated Sketchpad which used stroke based gestures using a light pen to manipulate screen-based graphical objects. Early example of touchless gestural interfaces for computer interactions by Bolt (1980) involved manipulating graphical objects through body gestures and speech through his intervention *Put that there*. In the past decade, body gestures in form of hand and body movements have been explored to control, manipulate and navigate across computer enabled applications. Hand movements (e.g. hand moving left-right-up-down, two hands panning across screen etc.) are used to manipulate electronic presentations in form of next-previous slides, zooming into figures, scrolling up-down, highlighting text etc. (Fourney et al., 2010; Baudel and Beaudouin-Lafon, 1993), extend mouse and keyboard interactions (Hermann, 2004), in musical applications to control and navigate across media library (Löcken et al., 2012; Hayafuchi and Suzuki, 2008; Henze et al., 2010), creation of user generated music (Karjalainen et al., 2006; Tarabella, 2005), controlling user interaction on 3D geographical maps using motion tracking technologies, e.g. Nintendo Wii and Microsoft Kinect (Francese et al., 2012), freehand drawing on desktop interface (Mo et al., 2005) and controlling user interfaces of 3D virtual world (Li et al., 2009; Bowman et al., 2004). Static freehand gestures have also been incorporated to control on-screen cursor movements aimed to reduce motor efforts for older adults, motor impairment users and young children (Saleiro et al., 2009).

2.3.4.2 Gestural interfaces for health and disability improvement

One of the advantages of gestural interfaces is mandatory body movements as input, which increases the possibility to improve physical and motor related impairments. Assistance for physically disabled users in controlling the robotic aid to assist with a repositioning process and controlling a mouse and other input devices have been experimented through facial gestures and expressions (Krishnaswamy and Kuber, 2012). Full body motion control games for older adults experiencing age related changes and impairments (Gerling et al., 2012) has been developed for them to remain active and engaged. Authors report higher acceptance, ease of use and increase range of motion of body movements seen in older adults. Touchless gestural interfaces allow manipulation of interfaces from a distance which can be effective in the risk of contamination, especially in hospitals. Bigdelou et al., (2012) proposed a gesture framework for a computerized medical system which can be controlled through personalized body gestures defined by surgeons. A study conducted with 10 participants demonstrated sufficient control, easy to adapt and overall satisfaction to operate gestural interface. Similarly, body gestures in medical and health systems are also used to manipulate visualization of large medical data (Kirmizibayrak et al., 2011), retrieval of medical images from Picture Archival and Communication Systems (Widmer et al., 2014).

2.3.4.3 Gestures for TV control and manipulation

Gestures have also been investigated as input modalities in home entertainment and TV interfaces. One of the early examples of using dynamic hand gestures for TV control has been proposed by Freeman and Weissman (1995) who used a mouse like cursor behavior on the screen to match with user performed gestures. Similar investigation on TV control has been conducted to compare two different menu techniques – radial and rotary menus on TV interface (Chertoff et al., 2009), to investigate acceptance and performance of freehand gestures to control volume and channel function for TV interface designed for older adults (Bobeth et al., 2012) and to investigate effectiveness and accuracy of eyes free palm based interface to control TV interface (Dezfuli et al., 2012).

2.3.4.4 Gestural interfaces for games

Freeman et al., (1996) proposed interactive games which tracks players' hand and body motion to control movement and orientation of objects (e.g. car). Konrad et al., (2003) uses perceptual techniques, mainly the passive and untethered sense of users' pose and gesture to maneuver through virtual worlds. Paiva et al., (2002) proposes expressive gestures associated with anger, fear, surprise, sadness and joy to influence to emotions of the character they control in a virtual game called SenToy. The results suggest that participants easily adapt to expressing emotions through the gestures with the toy. Input, control and manipulation of objects and avatars of virtual reality games through tracking body gestures have been explored by Segen and Kumar, 1998 and Nishino et al., 1998. Similarly, Ng et al., (2009) presents user's silhouette to interact with on-screen 3D objects in order to provide a virtual experience of "chapteh" – game played in the villages of Asia.

2.3.4.5 Gestures in other computing domains

Gestures have been incorporated as input modality in a large number of computing domain. Gestures in virtual reality applications have been commonly used in the past decade. Hand gestures to arrange virtual objects and navigate through a 3D environment (e.g. graph etc.) (Segen and Kumar, 1998; Nishino et al., 1998; Osawa et al., 2000; Kirmizibayrak et al., 2011), hand gestures to control avatar expressions and movements (Berrientos et al., 2002) and full body gestures and tracking to model complicated avatar movements within virtual world (Thalmann, 2000; Maes et al., 1997; LaViola et al., 2001) has been explored. Hand and body gestures have been incorporated in an augmented reality (AR) display in selection and manipulation tasks (Buchmann et al., 2004), investigated intuitiveness of gestures in AR among children (Lagerstam et al., 2012), manipulating virtual objects of 3D space in AR (Bai et al., 2013), robotic interactions to control robot's hand, arm and body movements to reach and manipulate real objects (Goza et al., 2004) and smart room environments to control lights, entertainment systems and domestic appliances (Crowley et al., 2000; Wilson and Shafer, 2003; Fails and Olsen, 2002; Nickel and Stiefelhagen, 2003). Similarly, gesture supported manipulations on physical objects (E.g. moving, bumping, squeezing etc.) to communicate information about the users (Hinckley, 2003; Harrison et al., 1998), gesture input on a wearable device to provide in-time information (Feldman et al., 2005), control smart appliances (Tsukadaa and Yasumurub, 2001) and allowing older adults to interact with a projector based smart ambient environments to support daily activities and reduce memory problems (Yamamoto et al., 2010) are explored in order to investigate the role of gestures in other computing domains. Despite the challenges of mandatory body movements as input, gestures operated on pendant device as interaction medium have been proposed by Starner et al., (2000) to support home automation systems and medical support such as medical diagnosis, therapy and emergency services.

2.3.4.6 Gestural interfaces in other contexts

Gestural interfaces have been experimented in kitchen environment as input modality to navigate across recipes, timer and control a music player to overcome a situation of messy hands in a kitchen (Panger, 2012). Participant felt successful and in-control using the system, however possessed challenges of accidental commands. Similarly, gestures in performing arts to record ballet movement's position and poses and to provide real time instructional feedback, capture live motion and present the difference of dancers (Marquardt et al., 2012), manipulating a vehicle's secondary control (e.g. radio, heating etc.) to enhance safety by reducing the effort to reach out for vehicle controls (Pickering et al., 2007) and to understand users' cultural background by analyzing patterns of gestural expressivity (Rehm et al., 2008) have also been investigated.

2.3.4.7 Design guidelines for gestural interfaces

Often prior research has focused on technological accuracies for gesture recognition; however few researches have also been conducted in designing and framing guidelines for usable gestural interfaces. Earlier, Baudel and Beaudouin-Lafon (1993) presented guidelines with a focus on providing fast, incremental and reverse actions, use of gestures for appropriate tasks and using tensed gestures for starting positions. Jetter et al., (2010) and Norman and Neilsen (2010) proposed guidelines with a special focus on ease of performance and remembrance, intuitiveness, logical towards functionality and ergonomically suitable for less physical stress while performing gestures. Similarly, appropriateness of application for gesture as input, users' sensory motor skills, absence of intermediary device, mapping of tasks to hand positions, adaptability of gestures, coordination of many degrees of freedom and real time control have been reported by Sturman and Zeltzer (1993). User characteristics' specific guidelines have also been presented for older adults with additional heuristics of easy gesture recall, age inclusive design, range-of-motion adaptability and simple setup routines (Wild et al., 2004; Kirmizibayrak et al., 2011). Use of locomotion in short travel tasks, environment to adapt from natural locomotion to compensated locomotion, provide a way to recall in-game interactions, reducing fatigue and use of body-centric gestures have been reported for steering and locomotion focused full body gesture interaction enabled action games (Norton et al., 2010). Saffer (2008) proposed important characteristics such as discoverable, trustworthy, responsive, appropriate, meaningful, playful and pleasurable for designing usable gestural interfaces.

2.3.4.8 Evaluating parameters

Earlier research aimed at implementing systems, applications or interfaces have not performed any form of evaluation or provided any results about the effects of usability in terms of accuracy or any other features of their system (Karam, 2006). Recent studies, especially post 2005 research work has showcased a trend of evaluating gestural interfaces on different parameters. Task analysis and characterization (Adamczyk and Bailey, 2004; McCrickard et al., 2003; Wild et al., 2004; Czerwinski et al., 2004), system performance and error analysis (Marquardt et al., 2012), subjective usability and perceived sense of presence and immersion (Ng et al., 2009), perceived usability, usefulness and acceptability through pre-post game questionnaire, direct observation and semi-structured group interviews (Bigdelou et al., 2012; Francese et al., 2012; Vatavu, 2012; Rice et al., 2011), comparison on gestures with input modalities through time taken (Kirmizibayrak et al., 2011;

Widmer et al., 2014), social acceptance through factors like culture, time, user's position in an innovation adoption curve (Montero et al., 2010), performance in form of task completion time-error rate and user acceptance (Bobeth et al., 2012; Gerling et al., 2012), gesture consistency, remembering ability and delightfulness (Löcken et al., 2012) have been frequently evaluated for gestural interfaces. Most of the studies have used video observations, semi-structured interviews to gather users' reactions and comments and Likert scale technique to investigate user acceptance of gestural interfaces.

2.4 ICT interventions in maternal health care

ICT enabled services especially mobile phone based interventions have been investigated to empower local health workers of developing regions. DeRenzi et al., (2012) developed an automated Short Message Service (SMS) to remind Community Health Workers (CHW) to visit their clients who have not been visited for 28 days or more, with an aim to reduce the situation of adverse health effects on their clients. The study leveraged the existing m-Health projects which provided mobile phones to CHWs and developed SMS reminders to improve routine health center visits. Similarly, a study to teach local health workers about healthy pregnancy habits with an aim to increase their motivation and participation of key community influencers was conducted by Ramachandran et al., (2010). A series of 7 one-minute videos were developed on danger signs that occurred during pregnancy and how to take actions on it. A short video testimonial was also made showcasing village Sarpanch (president) speaking about anemia and role of ASHA in prevention of such diseases. Chib (2010) designed a mobile midwife project which used mobile phones to transmit health statistics to a central database, contact coordinators and peers for health advice and information, communicate with doctors and patients in Aceh Besar, Indonesia. The study conducted with 233 midwives suggested mobile phones to be effective in facilitating smoother communication and allowed speedy emergency response. *M-Sakshi* (Gautham and Free, 2012), multimedia (sound & illustrations) enabled mobile application was designed to provide interpersonal counselling to ASHAs to improve their knowledge on maternal and newborn healthcare. A study conducted with 25 ASHAs revealed significant improvement in their knowledge where 70% of ASHAs could identify at least 3-5 danger signs as compare to 48% of ASHAs at a baseline. A mobile application interface for data collection, integration, and continuum of pregnancy and child care for rural health workers in India has also been developed by Maitra and Kuntagod (2013). Timely pregnancy related management information and relevant pregnancy and childcare services were given to health workers of Karnataka, India.

Information access directly to PW has also been explored through ICT. An audio-visual mobile application interface was designed to impart maternal health education among low literate mothers of rural India where information such as dos & don’ts of pregnancy were provided on a low cost feature phone (Tiwari and Sorathia, 2014). Pai et al., (2013) designed an automated voice call system to remind and promote adherence of iron supplements among low literate PW in India. Enquist and Tollmar (2008) proposed novel ways of sharing information between health care recipient and providers in Denmark. Authors designed an interactive device providing PW with a tool to collect and review clinical and personal information concerning their pregnancies. The information stored in the device provided relevant instructions, recommendations, intimate photos and diary notes. Parmar et al., (2009) designed a tangible user interface for accessing information related to menstruation and maternal health in eastern India. 7 tangible buttons called “information candies” provided unique health information about pregnancy, problems related to maternal health, references to urban women practices, puppet movie shows and benefits of medical treatment. The study aimed to increase social interaction and community decision making in order to empower them with menses and maternal health information.

Despite having the same objective to improve maternal health conditions, the approaches reported in existing explorations and investigations are very different. Most existing ICT interventions on maternal healthcare are targeted to health workers, where studies have suggested unhealthy practices, unwillingness and lack of motivation among health workers to promote healthy maternal and child health services, especially in rural areas of developing regions (Agarwal et al., 2010; Ganle et al., 2014). Studies targeted to empower PW are also limited to tracking, monitoring and imparting basic health information as independent alternative instead of leveraging the potential and infrastructural outreach of government supported health initiatives. Moreover, the existing research is investigated upon mobile phones which is often used as a shared resource among family members and local community, faces challenges of poor usability, lower connectivity and lower technology literacy among rural users. Effectiveness of these interventions is investigated through a task based evaluation approach, instead of prescribing loose activities that result in realistic findings (Oulasvirta, 2011). Challenges faced in these projects provide an ample opportunity to use alternative approaches such as leveraging new interaction styles, directly targeting to affect beneficiary, contextual information and services and leveraging upon the existing government infrastructure, manpower and its outreach.

2.5 Critical appraisal of literature review

Maternal health is in immediate need for appropriate care, especially in developing countries accounting 99% of maternal deaths. This is even more critical for India which is responsible for highest maternal deaths across the globe. Despite increasing effort and growth in infrastructure development and policy initiatives towards maternal health, MMR in India is still devastatingly high (Census in India, 2013). Higher maternal deaths and MMR demands an undeniable need to provide reliable healthcare services to improve maternal healthcare and achieve safe motherhood.

The reviewed literature portrays ICTs especially mobile phones as an effective enabling tool for key development areas in resource scarce regions. Despite the positive outcomes, mobile phone supported ICT interventions face challenges in acceptance across user groups due to problems with poor usability, low technology literacy, contextually inappropriate use of technology and use of non-relevant modes of interactions which increases cognitive load and learning curve of these communication platforms. One potential direction to overcome such problems is the use of novel interaction mediums and modalities incorporating natural user interfaces adapted from familiar human-human communication.

The literature review also portrays human body gesture as a potential alternative as natural input to interact with digital interfaces with its wide varieties of applications in gaming, healthcare, computer application augmentations and interaction with a virtual world. Potential of gestures is not only limited to different application domains, but have extended its reach by incorporating a variety of users (e.g. older adults, children etc.) on various communication platforms (e.g. computer, TV etc.). In few cases, body gestures as input modality have also demonstrated user acceptance, efficiency and effectiveness across targeted user groups. Although gesture-based interfaces have been investigated in mainstream HCI for two decades, most investigations and experimentations have often targeted towards defining technological methods for accurate gesture detection and recognition. Moreover, studies examining gesture acceptance in HCI have been investigated across limited user groups, literate users with prior technology exposure and in a controlled environment. Moreover, proposed design guidelines for effective body gestures are also elucidated from lab controlled investigative studies; but challenges of field realities, socio-cultural issues and domain sensitivity are often not reported. Research on effective gesture based HCI is still in an infancy stage and acceptance and effectiveness of such interfaces in developing countries has not been sufficiently explored. It is rare to see gesture research targeting the needs and requirements of users with varying literacy levels in developing regions, especially with low literate users and socially relevant domains such as maternal healthcare.

This thesis moves towards gaining an understanding on acceptance of gestural interfaces and effectiveness of body-gestures as interaction medium among low literate users in resource scarce regions of developing countries. It believes that natural gestural interfaces aimed to improve maternal healthcare will find acceptance among the targeted user group. Moreover, design of a suitable gesturing style and gesture vocabulary will ensure natural and intuitive interactions which in-turn will prove effective over time to emerge as a future potential interaction medium among targeted user group.

This thesis uses the context of Assam, a north eastern state of India for exploration and investigation of gestural interfaces due its large influence it can have on a degrading case of overall maternal healthcare in India. The importance of the context of Assam in maternal healthcare is detailed out in the next section.

2.6 Assam – our chosen context

To pursue the research explorations, a north-eastern state of India, Assam is chosen. The reasons for selection of Assam as the chosen context for study are stated below.

a) Relevance of state of Assam to maternal healthcare – Assam has highest MMR in India contributing 390 deaths per 1,00,000 live births every year, which is nearly four times higher and undoubtedly far above MMR of India as well as proposed MMR in MDGs of 100 deaths per 1,00,000 live births every year (Census of India, MMR 2010-2012). Considering the severity of the problem and urgency to solve it, GOI has declared Assam as one of the Empowered Action Group (EAG) states. These indicators project Assam as a high-priority region and an immediate focus for research on maternal healthcare. Hence, Assam was chosen due to its high relevance to the topic of maternal healthcare.

b) Location, users and domain logistics – due to relatively easier access to health services, stakeholders, users and experimentation set up to IIT Guwahati where the researcher is presently working, Assam was chosen for the research context. The purpose of choosing accessible context was to get better understanding of the practices and challenges faced by people associated with maternal healthcare.

c) Challenges of geographical locations, especially with remotely located regions of Assam where access to healthcare services often face multiple difficulties such as inaccessible roads, low commutation and local transportation services (government as well as private), medication facilities, less number of health experts and health workers etc. Tea gardens located in hilly areas, river island of Majuli where access is only through river boats, Changsari etc. are some of the remote locations which face difficulties due to its remoteness. These locations are also home for nomadic communities such as Missing tribe, Rabha, Dimasa, Mikir and migrants from neighboring countries who possess low literacy levels and very little exposure to technological platforms (e.g. ATMs, mobile phones etc.)

Hence, Assam was chosen to understand the impact of technology interventions across socio-cultural issues, geographical diversities, users of varied education and technology literacy and for field realities.

2.7 Research hypothesis

Following points were hypothesized for this research work.

- Gestural interfaces in the domain of maternal healthcare is well acceptable among low literate users in resource scarce regions
- Learnability of body-gestures as interaction modality increases over time through subsequent interactions

2.8 Research aim and objectives

Research aim:

The aim of this research is to plan and execute a series of field based experiments through a user-centered design approach involving the target users of low literate PW of rural Assam. These experiments should verify the acceptance and learnability of gesture based interactive audio-visual content on the issues related to maternal healthcare. The aim of this research can be achieved through the following objectives.

Research objectives:

- To conduct field based studies in order to identify appropriate needs and problems experienced by PW and investigate influential factors that impact ICT interventions aimed at improving maternal healthcare in rural Assam in India
- To conduct field based experiments that help to design and execute appropriate gesture style and vocabulary suitable to the context and targeted user group
- To design a gesture enabled interface aimed at improving maternal healthcare in rural Assam in India
- To conduct field based experiments in order to investigate acceptance of gestural interfaces among low literate PW
- To investigate learnability of gestures as interaction modality over subsequent interactions with the system

2.9 Summary

Overall, this chapter presents the literature review of three focus research areas – maternal healthcare, ICT interventions and gesture-based interactions.

Through in-depth reporting and analysis of existing literature, this chapter establishes the need to investigate body-gestures as a suitable interaction modality to communicate to ICT platforms among low literate users in developing regions. It presents limitations of traditional ICTs, especially mobile phone based interventions such as poor usability, low technology literacy, language barriers and inappropriate interaction modalities. These limitations reduce its usage and impact among low literate users in developing regions. It further emphasizes the need to rethink the approach of designing ICTs through novel and natural interfaces that can be easily adapted and accepted by target users. With challenges of accurate recognition, multiple languages and dialect in effectively implementing and investigating speech interfaces, this chapter presents body-gestures as suitable alternative in order to increase the impact of ICTs in developing regions. This forms the research focus, which aims to (i) investigate acceptance of gestural interfaces and (ii) investigate learnability of body-gestures as suitable interaction modality. Maternal healthcare in rural Assam is chosen as a subject case example, whereas low literate PW women of rural Assam are chosen as a target user group for this research.

In the next chapter, studies investigating suitable system elements for designing gesture-based experiment are presented. It covers four major studies (i) contextual inquiry among people associated with maternal healthcare (ii) focus group study with health experts (doctors) (iii) focus group study with ASHAs and PW and (iv) participatory design study to generate suitable body-gestures. These studies are conducted to gather appropriate system design elements which form the gesture-based experiment for this research.

Chapter 3

Planning and Methodology for Gathering System Design Elements of Gesture-based Experiment

Acceptance, effectiveness and impact of ICT interventions depend heavily on its system design elements (Toyama, 2011; Heeks, 2002). This chapter presents planning details and methodology used to gather system design elements in order to conduct the gesture-based experiment. A series of four studies (i) contextual inquiry to understand user needs, problems and opportunity gaps (ii) focus group study with health experts (doctors) for content creation (iii) focus group study with ASHAs and PW to study effective information dissemination method and (iv) user generated gesture design are conducted to identify suitable design elements. They studied design elements associated with user needs and problems, socio-cultural issues, technology platforms, healthcare information, suitable body-gestures and user acceptable information communication methods. These four studies are strongly interrelated to each other and create relevant system design elements for formalizing the final gesture-based experiment for this research.

First, it presents an overview of contextual inquiry conducted with PW, health workers and family members in rural areas of Assam, India (section 3.1). Brief findings and insights are presented in section 3.1.1. The details of contextual inquiry, users and findings are presented in appendix B. This is followed by content planning exercise performed with health experts to generate healthcare information suitable for safe and healthy pregnancy. Maternal healthcare contents and related details are explained in section 3.2. Further, a focus group study conducted with PW and ASHAs with an aim to investigate appropriate communication patterns to deliver sensitive maternal health information is elaborated in section 3.3. This is followed by a gesture design study to investigate suitable gesture vocabulary through a participatory design approach (section 3.4). User generated gesture design method is adapted to conduct the study. This section starts with a detailed review of existing participatory design approaches for designing gestures and elaborates upon chosen approach of user generated gesture design for this study (section 3.4.1 & 3.4.2). This is followed by conceptualizing computational functions (section 3.4.2.1), discussion on methodology where details of participants and study context (section 3.4.2.2), and procedure (section 3.4.2.2.2) are elaborated. Gestures collected during the study are reported in section 3.4.2.2.3 followed by detailed discussions on chosen parameters of extracting appropriate gestures in *Results* in section 3.4.2.3. Final list of gestures along with their visual representations are presented in *List of finalized gestures* in section 3.4.3. Selection of suitable gesture recognition technologies for accurate detection of these gestures are discussed in section 3.4.4. The chapter is finally summarized in section 3.5.

3.1 Contextual Inquiry

Cultural preferences and biases, such as a spatial orientation of information, color semantics, cultural metaphors etc. influence usability of proposed systems where design elements may differ for different cultures and contexts (De Angeli et al., 2004). India, a country of multiple states, languages and dialects, literacy levels, socio-cultural-political norms and beliefs and technology exposure demands multi-dimensional investigative studies to understand the contexts and users. Hence, a contextual inquiry through a semi-structured interview approach was conducted in order to understand overall maternal health conditions, users' needs and problems, socio-cultural issues, information gap and technology literacy among rural PW.

Total 61 people associated with maternal healthcare were interviewed. Out of 61 people, 38 were PW, 10 were husbands, 11 were health workers and 2 were doctors of local health centers. PW were recruited through references of ASHAs and doctors, as ready-made database of PW of their community was available. Users from rural Assam were from lower middle-class families with an average earning of 4000 to 7000 ($90 to $140) per month whereas families residing in a tea garden earned INR 1400 to 1800 ($25 to $40) with most users being semi-literate or illiterate. Most users of tea gardens had migrated from different places in search of work. 2 PHCs, 2 SCs, 1 CHC and 1 anganwadi were visited during the study.

3.1.1 Insights and findings of the contextual inquiry

Data gathered from contextual inquiry across 61 people associated with maternal healthcare resulted in 4 major findings – (i) Need for imparting appropriate and timely maternal health information (ii) high dependence on ASHAs (iii)gender issues in social system and (iv) familiarity and acceptance of TV interface. These four sections are elaborated in appendix B. Overall, the inferences identified from the findings strongly suggests lacks of basic pregnancy knowledge among PW, high influence of local health workers-ASHA in persuasion and motivation for availing health services, high regards and cordial bonding between PW and ASHA, high prevalence of gender issues and familiarity with TV interfaces. The study establishes a clear need to empower PW with pregnancy related information. This information should not be limited to a mere demonstration of government health schemes, but also portray how it is done and its significance, motivating them to avail services with care. Information demonstrating dos and don’ts of pregnancy and information specific to the context, such as existing food habits can add new benefits towards the goal of healthy motherhood. A cordial relationship and high regards to ASHAs can also be leveraged to effectively impart relevant health information. This is supported by gender bias towards females to discuss pregnancy issues which suggests interactive system with female characters for higher acceptance. Usage of socially influential actors, often called personas has earlier been portrayed effective for information dissemination (Agarwal et al., 2010). The study also suggests low usage and low literacy of a mobile phone, which demands interventions on familiar platforms such as TV for quick technology adoption and acceptance.

3.2 Creation of maternal health contents

The contextual inquiry demonstrated lack of healthcare information among targeted rural PW despite high motivation for healthy pregnancy. In order to investigate suitable maternal healthcare contents for information dissemination, a focus group study was conducted with health experts. Following section details out the methodology and findings.

3.2.1 *Methodology to create maternal healthcare contents*

A focus group study with health expert was conducted to create maternal healthcare contents. Two health experts in form of medical doctors were recruited. One doctor was a medical officer in a PHC and other one was a practicing gynecologist from Guwahati in Assam. The study was conducted at a university lab, where the details of the contextual inquiry were presented to doctors. A list of maternal health contents identified from a web resource of *Pregnancy – week by week* retrieved from www.babycenter.com was also presented to them in order to provide a starting reference and further approve, modify, eliminate or add upon presented contents based on their medical understanding, knowledge and experience. A brief discussion on inappropriate body-gestures dangerous for PW was also conducted in order to eliminate gestures or gesture categories impacting the health of PW.

3.2.2 *Insights and findings of focus group study with health experts*

The inferences of findings from the focus group study are presented in following sections.

3.2.2.1 Contents on maternal healthcare necessary to educate PW

Focus group discussion and consultation with doctors resulted in 3 major categories of information, necessary to disseminate among rural PW. Doctors defined following 3 broad categories and further elaborated on suitable contents under each category relevant for a targeted user group. The proposed 3 categories are a) S&R b) T&C and c) FH. Following sections present the details of these categories.

3.2.2.1.1 Symptoms and Recommendations (S&R)

S&R are aimed to educate PW about common problems and symptoms identified during each trimester of pregnancy. It presents relevant recommendations to overcome the identified problems. The contents were further divided into 3 trimesters to suit the bodily requirements and their relevance to each PW. Following contents are proposed for this section.

- Extreme tiredness	- Upset stomach	- Constipation problems
- Headache	- Constant heartburn	- Sudden weight loss
- Backache problems	- Fetal movements	- Body-itching
- Swelling problems	- Weight gain	- Clichy joints

3.2.2.1.2 Tests and Checkups (T&C)

T&C consist of all relevant pregnancy related tests, mainly the tests supported by government health services. T&C was not limited to mere imitation of tests from information brochures, but focused on explaining the significance of these

T&C on the advice of the doctors. For instance, few excerpts from information of ultrasound test stated that, "Ultrasound test helps to check the health condition of a child and mother. This is very important to learn about child's growth and betterment of PW for healthy pregnancy". Following contents are proposed for this section.

- Blood test	- Hemoglobin (HB) tests	- Random Blood Sugar (RBS)
- Ultrasound test	- Urinary test	- Iron test
- Thyroid	- TT injection	- Prevention of Parent to Child Transmission (PPTCT)

3.2.2.1.3 Food Habits (FH)

FH section consists of contextually available food along with their nutritional values to motivate PW to follow appropriate food habits. For example, an emphasis was given on consumption of a banana flower which is rich in iron content and locally available. Following contents are proposed for this section.

- Calcium rich food	- Fiber rich food	- Folic rich food
- Iron rich food	- Vitamin rich food	- Protein rich food

3.2.2.2 System supporting upper body gestures

The focus group study also briefly discussed about suitable gestures which can be easily performed by PW from all trimesters. This discussion was aimed at eliminating the possibilities of any unwanted physical damage while performing gestures. Doctors denied the use of lower body gestures (body-parts below stomach), especially for 2nd and 3rd trimester PW due to possible negative impact on their body-balance. This may further result in sudden fall which is dangerous for PW in 2nd and 3rd trimesters. Upper-body gestures were recommended suitable over lower-body gestures for PW from all 3 trimesters. They also recommended providing alternatives of sitting and standing position enabled gestures, especially for 3rd trimester PW. Due to higher nausea feeling in 3rd trimester, it may be dangerous to perform gestures in standing position for 3rd trimester PW.

3.2.3 Concluding comments on focus group study with health experts

Overall, a focus group study with doctors was conducted to generate maternal healthcare contents in order to overcome the challenges of lack of information and to educate PW. The insights identified from this focus group study revealed two important elements for designing a gestural system – (i) First, it presented 3 categories of maternal healthcare information – pregnancy related S&R, T&C and FH which were designed covering health information of 3 trimesters, contextual limitations and availability of local resources and (ii) second, use of upper body gestures to operate a gestural system in order to reduce unwanted accidental damages, especially for 2nd and 3rd trimester PW. Although, this cannot be directly used in the system, it certainly proposes for extracting the first layer of body-gestures.

3.3 Study of appropriate method of health information communication

The contextual inquiry revealed lack of information among rural PW. A focus group study with doctors created suitable maternal healthcare contents necessary to educate rural PW. With established healthcare contents, it was important to understand an effective information communication method in order to increase acceptance of disseminated information. The findings from this study were aimed to design information communication modules for future ICT based maternal health system. Hence, a focus group study along with ASHAs and PW was conducted to understand existing communication patterns to impart maternal health education. ASHAs were chosen due to higher acceptance and high regards across rural PW.

3.3.1 *Methodology to investigate suitable information communication mediums*

The focus group study was conducted concurrently in two different rooms with total 4 ASHAs and 10 PW at a mini Primary Health Center (mPHC) in Bonmoja village. Each room included 2 ASHAs and 5 PW. During the study, ASHAs disseminated maternal healthcare information to PW. Maternal healthcare information generated by doctors in a previous study was chosen for this experiment. The session was conducted in Assamese language and was moderated by ASHAs. They were given freedom to use any preferred method (e.g. verbal, visual method through hand drawings etc.) to communicate health information. Figure [8] shows a focus group study conducted at one room of the mPHC. The study was video recorded with permissions for moderators and focus group participants. Each session was held for 40-45 minutes.

Figure 5. The focus group study moderated by 2 ASHAs at Bonmoja mPHC (the image is extracted from a recorded video of the focus group study)

3.3.2 Insights and findings of a focus group study with ASHAs and PW

The detail inferences of the findings of the focus group study are reported in following sections.

3.3.2.1 Instructional method for information communication

It was observed that ASHAs used instructional approach to communicate maternal health information. Moreover, the information was communicated verbally to PW. ASHAs verbally instructed PW to follow recommendations during their pregnancy. One such example where ASHAs instructed was, “All of you should eat small meals regularly. Eating heavy meals three times a day will increase constipation. Hence, eat smaller meals many times in a day to avoid stomach related problems”. In addition to verbal instructions, information was also enacted by ASHAs to effectively explain to PW. For instance, a common symptom of frequent vomiting during pregnancy was explained through enactment of vomiting to ensure easy understanding of the symptom.

3.3.2.2 Careful demonstration of sensitive information

Information related to abdomen and lower stomach areas were explained through a careful demonstration. Index finger pointing towards a stomach was used to demonstrate abdomen related maternal health information. For instance, vaginal problems were explained by touching the stomach with fingers pointing towards lower abdomen. It was observed that PW were very comfortable with this method and did not feel shy during explanation of abdomen related information.

3.3.3 *Concluding comments on a focus group with ASHAs and PW*

Overall, the focus group study revealed acceptance of instructional approach for communicating health information to PW. The instructions were given verbally in local Assamese language. Moreover, information presentation of lower body parts, especially lower abdomen demanded a different approach to communicate instead of simply imitating a visual representation of body parts along with verbal instructions. The findings of this study will help in designing information modules, especially for effective and contextualized information communication that can find acceptance among a targeted user group of rural PW.

3.4 Study of investigating suitable body gestures

Previous studies identified relevant maternal healthcare information and effective communication methods, the next step was to investigate body-gesture that is suitable to users and the context. These gestures were to be used to interact with maternal health information gathered through focus group studies explained earlier. This section presents the study of investigating suitable gestures through participatory design approach. It starts with a detailed presentation of existing participatory design approaches for designing gestures and elaborates upon chosen approach of user generated gesture design for this study. This is followed by details of methodology used to study body-gestures, e.g. conceptualizing computational functions (section 4.2.1), details of participants and study context (section 4.2.2.1), and procedure used for investigation (section 4.2.2.2). Gestures collected during the study are reported in section 4.2.2.3 followed by detailed discussions on chosen parameters of extracting appropriate gestures in *Results* in section 4.2.3. Final list of gestures along with their visual representations are presented in *List of finalized gestures* in section 4.3. Selection of suitable gesture recognition technologies for accurate detection of these gestures are discussed in section 4.4.

3.4.1 Overview of existing participatory approaches to designing gestures

With earlier experiments often focused on accurate gesture detection through design of new algorithms, few researches in recent time have chosen participatory approach to design usable gestures. A common point observed in participatory approach suggests incorporating users in a design process. Nielsen et al., (2004) proposed a user generated gesture approach to derive a usable gesture set through a collection of user created gestures. Functions of the proposed system are conceptualized to present across users. Gestures elucidated from users are further extracted based on semantic representation of associated functions. Henze et al., (2010) built on Neilsen's method and proposed to validate the outcome of each step to derive gesture set. The process employed usage functions combined with participatory design to define a gesture set which is further evaluated and improved. This method was found very similar to approach proposed by Nielsen et al., (2004). Wobbrock et al., (2009) proposed participatory design approach to derive basic gestures for surface computing. Similar process of participatory design and observation based design approach was adopted by Akers (2006) to find set of gestures for 3D selection of neural pathways. He explores two design methods – gesture brainstorming, a wizard of Oz method for early prototyping of new interfaces and gesture log analysis, a machine learning based log analysis method for improving existing interfaces. This method focuses on what people do with gestural interfaces instead of relying exclusively on what they say. Wobbrock et al., (2005) proposed a guessability study methodology that uses think-aloud protocol and video analysis to obtain qualitative data to illuminate users' mental models. The effects of gestures are presented to participants to elicit the causes meant to evoke them. Quantitative measures such as gesture timing, activity and preferences are logged using custom build software which helped them portray a set of user defined gestures.

Overall, above methods involve users in the design process and expound gestures from users' input. While methods proposed by Wobrrock et al., (2009), Wobbrock et al., (2005), and Akers (2006) are investigated and preferred for small screen and mobile interfaces, Nielsen et al., (2004) proposed user generated gesture method is independent of computing platforms and screen sizes. Moreover, this method does not require an early prototype interface, unlike (Wobrrock et al., 2009; Akers, 2006). Hence, a user generated gesture design method proposed by Neilsen et al., (2004) was employed to design gesture set suitable to context and users.

3.4.2 User generated gesture design – methodology of the gesture design study

For the purpose of this research, a user generated gesture design methodology proposed by Neilsen et al., (2004) was employed to elucidate user created gestures. The methodology was employed by following 3 steps mentioned below.

a) Defining computational functions – Identification of functions accessed through gestures are identified by conceptualizing the system
b) Finding logical gestures – investigate user created gestures for identified computational functions.
c) Gesture extraction – extract suitable gesture identified in step (b). The extraction is based on frequency, logical mapping to the computational functions, elimination of false positives across gestures and technical limitations

3.4.2.1 Defining computational functions

Findings from the contextual inquiry suggested consistent lack of awareness and education of maternal healthcare information. For this stage of gesture design study, a broad conceptual framework was developed to identify functions aimed to impart maternal health education among PW. As 3 health information categories were designed in consultation with doctors, a section demonstrating all 3 categories is needed. Hence, a section name *Activate Menu* was conceptualized where the main 3 categories of health information are presented. As multiple categories along with multiple health information is presented, a function to choose desired health information is needed. Hence, a computational function of *Select* was designed to choose preferred health information. These categories of information should also be allowed to view at once, demanding a new set of functions to navigate across health information. The navigation should support moving across *Next* and *Previous* information topics, *Pause* the demonstrated health information and *Resume* it again whenever needed. Given the novice nature of targeted user group, a function assisting them during non-desired and difficult interactions was needed to support users. Table 1 presents the list of conceptualized key computational functions, which will further be presented as task to investigate user preferred gestures.

Sr. No.	Functions	Description
01	Select	Choose a given option or information
02	Pause	Temporarily stop an ongoing activity (video/animation)
03	Resume	Restart the paused activity (video/animation)
04	Next	Move to next topics
05	Previous	Move to previous topics
06	Activate Menu	Move to home screen
07	Help	Seek assistance

Table 1: List of conceptualized computational functions and their description

3.4.2.2 Identification of logical gestures

3.4.2.2.1 Participants

24 PW were recruited from Bonmoja mPHC of a remote region of Changsari. Participants were chosen with the help of local health workers-ASHAs. The mean age for all participants was 25.3 years. Overall, participants were low literate with low technology literacy. Out of 24 participants, only 2 were graduates whereas 6 were above 10^{th} grade, 13 were below 10^{th} grade and 3 were completely illiterate. No participant had any prior experience of using a computer or gestural interface systems. Their technology literacy was also limited to TV usage (mainly for channel and volume changes) and mobile phones. Out of 24 PW, only 4 of them had their personal mobile phones whereas others used a mobile phone as a shared resource with other family members. All participants or their family members owned feature

phones, which were mainly used for calling – to related family members and for business purposes.

3.4.2.2.2 Procedure

Participants were called to Bonmoja mPHC for the study. One-to-one interview approach was chosen to conduct the study. One-by-one computational functions were presented (through verbal instructions & scenario) in random sequences. No screen or any form of interface was presented to the participants. Participants were asked to imagine that they had 5 Assamese songs to choose from.

The transcript included,

"Imagine your favorite 5 Assamese songs listed in front of you. There are certain set of tasks you need to do to listen to them…"

They were then asked to perform each function in form of a task. For example, "If you had to choose your most favorite song among the (hypothetical) list through performing a body-gesture, how would you choose that?" They were asked to perform at least two natural gestures for each given task. Participants were requested not to discuss the tasks with other participants till the study was completed. 2 teams of ASHAs in pairs were asked to moderate the session in order to achieve most natural gestures for each function. ASHAs were briefed prior to the study and were also given a transcript of the tasks. Both sessions were conducted in parallel in different rooms of Bonmoja mPHC. The sessions were video recorded with permission from the participants. Each session was 15-20 minutes long. Figure 9 presents moderators conducting an experiment and participants performing gestures on given tasks in two different setups.

Figure 6: ASHAs moderating a session for "identification of logical gestures" study in two different rooms of Bonmoja mPHC (the images are extracted from a recorded video)

3.4.2.2.3 Collection of user generated gestures

The video recordings of generated gestures were subsequently analyzed in the university laboratory. Total 49 different gestures performed by 24 participants were collected representing 7 computational functions. Table 2 presents user created gesture collected during the study. In table 2, italic text represents a category of gesture with normal text representing the variations performed in the explained category.

Function	User generated gestures	Frequency
Select	*Deictic Pointing*	22+1*
	Pointing with stretched arms	13
	Pointing with arm close to the body	9+1*
	Grab	1
	Number – showing no. using fingers (e.g. index finger for no. 1) to select information	1
Pause	*Emblem Halt*	24
	Halt once with right stretched arm	11 + 2*
	Halt twice	9 + 1*
	Halt with palm down	4
Resume	*Iconic as Comeback gesture – I (forearm & elbow towards the body – palm facing upward direction)*	9 + 2*
	forearm and elbow movement together (once)	8 + 2*
	forearm and elbow movement together (twice)	1
	Iconic as Comeback gesture – II (forearm & elbow towards the body – palm facing downward direction)	6 + 2*
	Stretch arms with straight palm and the bring it near the right shoulder	2
	Pointing a finger and tap	1
	Pointing	1
	Iconic as pressing a TV remote control button	1
	Horizontal movement (right to left)	2
	Iconic as turning a Knob	2
Next	*Vertical arm movement*	6
	Arm movement from upwards to down	5
	Arm up to down with pointing	1

	Horizontal arm movement (right to left)	7
	Horizontal arm movement (left to right)	3
	Deictic pointing twice	1
	Iconic comeback gesture I	4
	Iconic comeback gesture II	3
Previous	*Vertical arm movement*	6
	Arm movement downwards to upwards with arms closed to body	4
	Arms stretched and palm movement down to up	2
	Horizontal arm movement (left to right)	7
	Arm front to back	1
	Horizontal arm movement (right to left)	4
	Halt (dynamic push)	5
	Right arm/palm push gesture	4
	Turn a back little and push	1
	Iconic Lift gesture from right to left	1
Activate Menu	*Half circle (right to left palm movement)*	3
	Emblem Bye (Wave)	2
	Iconic paper turning gesture (three times)	1
	Emblem Namaste	4
	Iconic Go gesture	1
	Emblem Halt	1
	Metaphoric as "Bringing two arms closer"	11
	Gesturing a full circle	1
Help	*Raise right arm*	17
	Raise right arm and call once	8

	Raise right arm and call twice	2
	Raise right arm	7
	Two arms stretched and come back with palm downwards	1*
	Iconic Begging	2
	Come back gesture I	2
	Come back gesture once	1
	Come back gesture twice	1
	Emblem Halt	1
	Two arms wide up-down	1
	Pointing	1
* represents gesture performed as users' second choice		

Table [2]: Collection of user generated gestures for "Identification of logical gestures" study

3.4.2.3 Results

Several gestures were performed by the participants for the given tasks in the gesture design activity described above. To identify and extract suitable gestures out of the pool of all the gestures performed, the following acted as determinants a) frequency of the gesture performed b) logical mapping of the gesture to the function c) technical constraints and limitations and d) towards minimizing the possibility of false positive. Moreover, few computational functions such as *Pause-Resume* and *Next-Previous* which represent dichotomous referents were also considered while extracting appropriate gestures. Dichotomous referents are functions which logically represent reversible activities. The following description presents elucidated gestures for each function and discusses them in detail.

Pointing was an obvious choice to represent the *Select* function based on the frequency of the gesture performed - 23 out of 24 users. Two possibilities for the gesture were considered, a) pointing with stretched arms and b) pointing with arm close to the body. Hence, participants could perform *Pointing with or without stretched arms*, as per their convenience (figure 10).

Figure 7. (a & b) Two participants performing *Pointing* to demonstrate *Select* in the presence of moderators (the images are extracted from a recorded video) (c) line diagram representing *Pointing* gesture

Similar to *Select*, all participants (24/24) performed emblem *Halt* to represent *Pause* function. Few variations such as halt twice and halt with a palm in downwards direction were also performed, but they were found to be semantically presenting the same gesture. Considering the frequency of performed gestures, *Halt with & without arm stretched* was chosen as an appropriate gesture to present *Pause* function (figure 11).

Figure 8. (a & b) Two different participants performing *Halt* gesture to demonstrate *Pause* function in the presence of moderators (the images are extracted from a recorded video) (c) line diagram representing *Halt* gesture

A variety of gestures such as iconic come back gesture, pointing, knob like actions etc. were performed to present *Resume* function. Come back gesture with forearm in an upwards and downwards direction was performed 11 and 8 times respectively by the participants. They are called come back-I and come back-II respectively here. Given the opposite correlation between Pause and Resume functions, *Come back* gesture was found suitable for *Resume* function. Moreover, *Come Back* gesture semantically presents to call the function back to normal state, which was temporarily stopped due to *Pause* function. Come back-I was performed more than come back-II by participants. Given its correlation with *Pause* function and high frequency of performed gesture, *Come Back I* was found suitable to present *Resume* function (figure 12). Deictic *Pointing* had already been extracted for *Select* whereas iconic turning a knob had few performers, hence they were not considered suitable for *Resume* function.

Figure 9. (a & b) a participant performing *Come Back I* gesture to showcase *Resume* function in the presence of moderators (the images are extracted from a recorded video) (c) line diagram representing *Come Back I* gesture

Next function aimed to demonstrate next topic/information for the proposed information system. Gestures such as vertical arm movement (upwards to downwards) and horizontal arm movement (left-to-right & right-to-left) were performed by the participants. These gestures presented progressive navigation of information, however may contradict participants' mental model if the information presentation is not correlated with gestures (e.g. vertical arm movement to navigate an image from right to left). Since the system conceptualized to propose right-to-left transition of information, *Horizontal Arm Swipe (right-to-left)* was extracted for *Next* function (figure 13). Deictic *Pointing* and *Come Back* gestures had already been extracted for *Select* and *Resume* respectively, so were dropped in this case.

Figure 10. (a, b & c) A participant performing *Horizontal Arm Swipe (right-to-left) g*esture for *Next* function in the presence of moderators (the images are extracted from a recorded video) (d) line diagram representing *Horizontal Arm Swipe (right-to-left)* gesture

Gestures such as vertical arm movement, iconic lift taking and horizontal arm movement (left-to-right and right-to-left) were performed for *Previous* function. Considering the reversible activities of *Next* & *Previous* function and frequency of performed gestures, *Horizontal Arm Swipe (left-to-right)* was chosen suitable for *Previous* function. It is important that the chosen gestures do not occur unwittingly. Hence, gestures for *Next* and *Previous* functions were restricted towards its motion above stomach only and defined the range of motion beyond stomach. This was done to reduce the possibility of falling due to excessive bending, to eliminate the possibility of getting false positive for two gestures due to random hand movements.

Metaphoric *Bringing Two Arms Together* (figure 14) was chosen for *Activate Menu* function due to its high preference. Moreover, it demonstrated a metaphoric representation of bringing things together which is the ultimate aim of *Activate Menu*, i.e. to bring all information at one place. Gestures lying in similar category such as paper turning (thrice), drawing half circle and full circle would have been tiring for participants when performed multiple times. *Halt* was already taken for *Pause* and was hence dropped while *Namaste* (e.g. greeting) was performed as a second priority gesture.

Figure 11. (a, b & c) a participant bringing both her arms together to demonstrate *Activate Menu* function in the presence of moderators (the images are extracted from a recorded video) (d) line diagram representing *Bringing two arms together* gesture for *Activate Menu* function

Variations of *Raising the Right Arm (usually performed to draw attention)* were performed by 17 out of 24 participants to represent *Help* function. These gestures demonstrated a help call for someone at a distance asking “hello, can you come here to help me?” Gestures such as *Halt*, *Pointing* and *Come back* had already been finalized for other functions. Gestures such as iconic begging may not be culturally acceptable in the targeted user group. To eliminate false positives due to other gestures or through routine arm movements, *Raising any Arm* was defined to

Raising any arm above head for 2 seconds. It would not be physically tiring since *Help* function is not a core function to operate the system, but evoked only for assistance.

Figure 12. (a) a participant raising her arm to demonstrate *Help* function in the presence of moderators (the images are extracted from a recorded video) (b) line diagram representing *Raising any arm above head for 2 seconds* gesture for *Help* function

3.4.3 List of finalized gestures

7 gestures were finalized to represent 7 computational functions. Following are finalized list of gestures presented in table 3 and visual representations are shown in figure 16.

Sr. No.	Function	Extracted gesture
01	Select	Pointing
02	Pause	Halt with & without arm stretched
03	Resume	Come back-I (Come back gesture with forearm in upwards direction)
04	Next	Horizontal arm swipe (right-to-left)

05	Previous	Horizontal arm swipe (left-to-right)
06	Activate Menu	Bringing two arms together
07	Help	Raising any arm above head for 2 seconds

Table 3: List of finalized 7 gestures for 7 computational functions

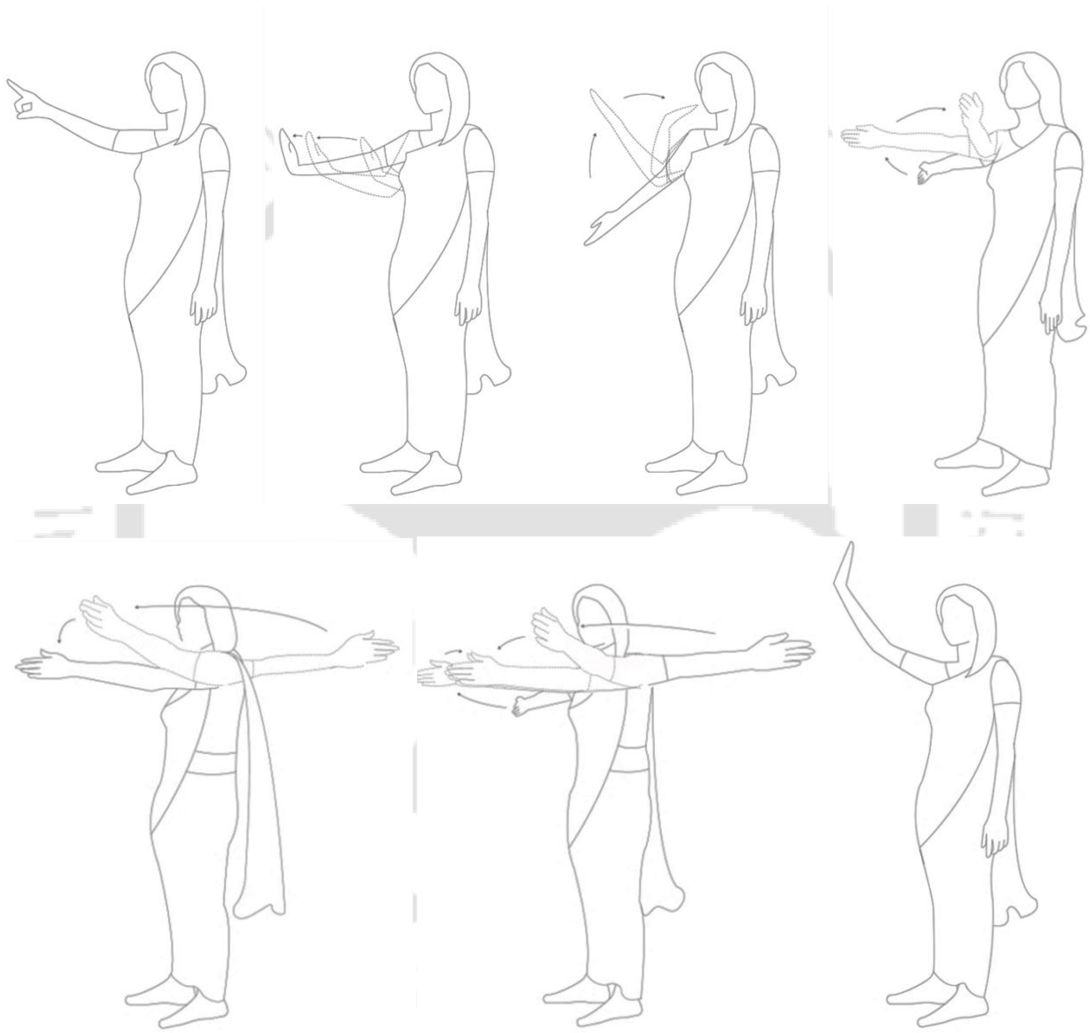

Figure 13: Final list of gestures (clockwise direction) – Pointing to *Select*, Halt with & without forearm stretched to *Pause*, Come back-I (Come back gesture with a palm in upwards direction) to *Resume*, Horizontal arm swipe (right-to-left) for *Next*, Horizontal arm swipe (left-to-right) for *Previous*, Bringing two arms together to *Activate Menu*, Raising any arm above head for 2 seconds for *Help*

3.4.4 Selection of technology for gesture recognition

7 gestures identified in the previous study demanded a technology support that can accurately detect upper body gestures for sitting and standing positions. Various technological methods and perspectives for a gesture recognition and detection such as a camera based HMM, motion path and accelerometer based HMM, motion path based gesture recognition, model and appearance based real time tracking approach, face pose recognition method, tracking a moving body in a sequence of camera images etc. have already been discussed in literature review (section 2.3.3.2). While these technology explorations provide a substantial start for accurate gesture recognition, they possess various limitations such as requirement of high quality cameras and computers, algorithms suitable to context and applications which often limits its usage for controlled lab environment. Such technologies have not been explored for non-controlled setup and on-field realities in developing regions where challenges such as multiple people intervening together, non-favourable environmental conditions, gesture detection for sitting and standing position and dust are often experienced. Moreover, such technologies are not readily available and demands high technical expertise and time for exploration which is out of the scope of this thesis. Whereas commercially available technologies such as Nintendo Wii™ – an accelerometer and infrared sensor based object detection and Microsoft Kinect™ – a RGB camera and infrared sensor based body gesture motion tracking technologies have also provided a strong basis of accurate gesture detection. These technologies are explored for on-field realities and have readily available SDKs for experimentations and explorations. Although Nintendo Wii™ and Microsoft Kinect™ both enable accurate gesture recognition, Nintendo Wii™ requires holding Wiimote control, which demands additional physical stress and cognitive load for novice users. Microsoft Kinect™ detects full body positioning and body movements accurately without the need to hold any object, allowing free body

movements. Hence, Microsoft Kinect™ was chosen as appropriate technology to suit the on-field nature of the project and extracted body-gestures.

3.5 Summary

Overall, this chapter presented four study experiments to gather suitable system design elements – through contextual inquiry among people related to maternal healthcare, conducting focus group studies with users and stakeholders and using participatory design approach for body-gesture generation. These studies aimed to identify opportunity gaps among rural PW, create maternal healthcare contents, investigate effective dissemination methods to communicate sensitive maternal healthcare information and generate suitable body-gestures. These studies revealed five major findings that formed core system design elements for gesture based experiment. First, it demonstrated a strong need to intervene to support and educate PW with necessary maternal health information. Second, it revealed social dynamics, hierarchy and gender issues in local communities, especially across people associated with maternal healthcare. This leads to defining important design decisions such as building female personas to influence the belief, attention and motivation of targeted users. Third is an identification of instructional communication as a key approach to effectively disseminate health information that has established acceptance among rural PW. This was further supported by identified design clues to impart sensitive health information (e.g. information related to lower abdomen etc.). Fourth, it presented the use of non-traditional ICTD platform of TV as a potential medium for information broadcasting to increase familiarity and acceptance of alien technology interventions. Finally, a series of 7 body-gestures - *Pointing, Halt with and without forearm stretched, Come back-I, Horizontal arm swipe (right-to-left), Horizontal arm swipe (left-to-right), Bringing two arms together* and *Raising any arm above head for 2 seconds* were finalized during the study. These gestures become input modalities to control and manipulate the gesture based experiment which is in form of ICT based maternal health information system presented in the next chapter.

Chapter 4

The Development of Gesture-based GUI

Chapter 3 presented four detailed experiments – contextual inquiry in rural Assam, focus group study with doctors, ASHAs and PW and user generated gesture design method to identify appropriate elements to design the ICT system. This chapter details out the design proposal for ICT system based on the findings identified and design directions analyzed from chapter 3 and 4.

4.1 Introducing *Chetna*

The findings consistently revealed lack of information awareness which defined a core objective of the proposed system to educate PW about maternal healthcare. With a clear focus on design intervention to create awareness about the necessary maternal health information, the system is called *Chetna* (meaning awareness).. 3 categories of information – S&R, T&C and FH are presented through an audio-visual medium in local Assamese language. The information is communicated through a TV platform due to PW's familiarity with TV interfaces. Due to PW's established trustworthy bonding and high regards for ASHAs, later are used as personas who will impart health education to PW through instructional communication approach. The system also accommodates female characters and other familiar elements to demonstrate all health information through audio-visual animation imitating real world health information communication identified from focus group study with ASHAs and PW (section 5.3.1 and 5.3.2). The system is designed to be installed at government health center (e.g. SC, mPHC, PHC etc.) due to their established database with almost all PW enrolled under NRHM to avail government supported benefits, existing infrastructure and manpower outreach.

Following the objectives of this thesis to investigate acceptance of gestural interfaces and learnability of body-gestures, the input modality for operating the interface is through body-gestures. Gestures associated with specific computational functions are used to control and manipulate the system's interface.

Overall, *Chetna* is a gesture enabled TV based health information system to educate and empower rural PW. It imparts audio-visual health information, especially related to healthy pregnancy in local Assamese language and uses familiar design elements. This chapter starts with elaborating on important sections of *Chetna* including health information, GUI design and gesture design followed by an overall structural and navigational flow of *Chetna.* It starts with a detailed explanation on structuring of healthcare information where specific contents of S&R (section 5.2.1), T&C (section 5.2.2) and FH (section 5.2.3) are elaborated. This is followed by layout design (section 5.3.1) and grid design (section 5.3.2) components of the GUI for the system. Structural and navigational flow of *Chetna* through step-by-step flow of user authentication, login, trimester selection, interactive tutorial, audio-visual interface navigation and feedback are explained in the section 5.5 followed by technical details and methods used for implementing the system (section 5.6).

4.2 Structuring of healthcare contents

3 categories of maternal health information – S&R, T&C and FH are demonstrated through *Chetna*. This information is further divided based on the trimester number of the PW. The categories of healthcare contents and trimester-wise break of information was done in consultation with doctors. This section presents the trimester-wise healthcare contents adapted for *Chetna.*

4.2.1 *Contents on Food Habits (FH)*

Information on FH was kept common across all trimester due to consistent need for healthy diet during each trimester. This decision was taken in consultation with health experts during the focus group study. Following are the list of FH finalized for *Chetna.*

- Iron rich food
- Calcium rich food
- Protein rich food
- Vitamin rich food
- Folic acid rich food
- Fiber rich food

The healthcare contents on FH explained the benefits of specific category and demonstrated locally available food supporting each category. For instance, an excerpt from iron rich food contents explains "iron rich food helps to avoid weakness, depression and helps in decreasing the chances of anemia. Banana flower has rich iron contents and is locally available to consume"

4.2.2 *Symptoms and Recommendations (S&R)*

This section presents health information related to common S&R during different stages of pregnancy. The contents of S&R for each trimester are presented below.

4.2.2.1 S&R for trimester 1

- Constipation problems
- Constant heartburn
- Extreme tiredness
- Upset stomach
- Continuous headache

4.2.2.2 S&R for trimester 2

- Fetal movements
- Swelling of body parts
- Stretch marks
- Backache problems
- Clichy joints
- Hair fall problems
- Itching problems
- Sudden weight gain

4.2.2.3 S&R for trimester 3

- Varicose veins
- Contraction
- Delivery overdue
- Piles
- Swollen ankle
- Breadth shortness
- Sleeping habits

4.2.3 *Tests and Checkups (T&C)*

This section presents health information related to government supported health schemes, especially T&C during different stages of pregnancy. The contents of S&R for each trimester are presented below.

4.2.3.1 T&C for trimester 1

- Blood group
- HB test
- RBS test
- Ultrasound test
- Urinary tract infection

4.2.3.2 T&C for trimester 2

- Iron test
- Thyroid test
- TT injection
- Ultrasound test
- HB test

4.2.3.3 T&C for trimester 3

- PPTCT
- HB test
- RBS test
- Ultrasound test
- Urinary test

4.3 Designing the Graphical User Interface (GUI) for *Chetna*

4.3.1 *Layout design of the GUI*

Layout design of *Chetna* involved design of 3 important components – virtual representation of ASHA as persona, virtual representation of PW to enact for presented information and design elements of the context. These 3 components were chosen as main elements of *Chetna* due to familiarity of targeted users with these design elements.

ASHAs were designed as system personas that acted as an instructor for the system and mainly communicated maternal health information. A virtual avatar of

ASHA (figure 18) was presented in the GUI aiding users to navigate through the interface. She also demonstrated health information through verbal instruction along with visual representation of health information.

Figure 15. Persona of ASHA used in *Chetna*

Each information was visually presented through a virtual PW imitating the presented health information. For example, virtual PW herself enacted for vomiting to visually demonstrate the common symptom of upset stomach, whereas virtual ASHA provided verbal commentary which elaborated on upset stomach, causes and methods to overcome the problems. Virtual PW wore a traditional Mekhala Chadar (a traditional sari of Assam) in order to provide a familiar feel the interface. Figure 19 showcases virtual avatar of PW used in the system.

Figure 16. A virtual agent of PW used in *Chetna*

Similarly, familiar elements of traditional Assamese home such as Jhapi (traditional hat), traditional bamboo structured house and Haloi (a metal based traditional container) were used as background to demonstrate S&R and FH which are often experienced at home. Figure 20 shows a traditional Assamese home along with a virtual avatar of ASHA and PW. A traditional health center layout with information brochures and relevant furniture was used to demonstrate T&C information which is often conducted at health centers as shown in figure 21. Position of virtual ASHA was kept constant on the left side of GUI layout whereas virtual PW and elements of traditional Assamese home were kept in the background.

Figure 17. GUI layout of virtual ASHA, PW and traditional elements of bamboo structured Assamese home – Jhapi and Haloi

Figure 18. GUI layout of virtual ASHA, PW and local health center look-alike environment

The information was provided in a local Assamese language through audio-visual animations. Sensitive information, especially information related to stomach and abdomen areas were demonstrated with special care. For example, an avatar of PW touched her stomach and gestured her hand towards abdomen area to explain symptoms of urinary infections. Similarly, symptoms of constipation and vomiting were presented through exhausted facial expressions along with PW touching her stomach.

4.3.2 *Grid design of the GUI*

A structure of grid design is presented in figure 22. The GUI is divided into 3 major sections. Central section (2 of figure 22) demonstrated major information of all health care contents through interactive animations. It also presented all primary options to users including trimester numbers (figure 23), icons of health care information etc. The icons in central sections were grouped together based on Gestalt's law of proximity. The icon sizes were kept 220*220 px suitable to Microsoft Kinect™ design guidelines (Kinect for Windows: Human Interface Guidelines). The distance between two icons was kept 180 px. The position of virtual ASHA was kept prominent according to rules of thirds. This was done in order to emphasize the presence of virtual ASHA and her instructions. Figure 24 shows a prominent position of ASHA for the GUI of *Chetna*

Figure 19. 1 & 3 – Controls related to the content being displayed at the center and 2 – Real estate reserved for major content demonstrations and primary options

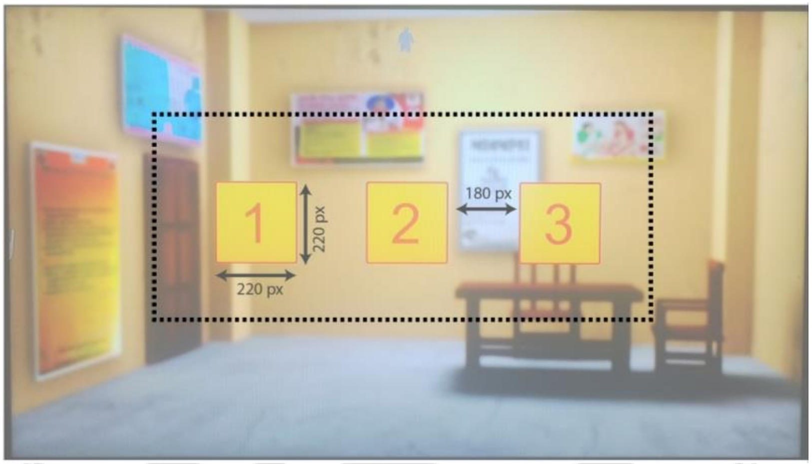

Figure 20. Similar items grouped together based on Gestalt's law of proximity

Figure 21. ASHA member strategically placed according to the rule of thirds for increased attention

4.4 Gestures of *Chetna*

Gestures for 7 computational functions were extracted through a user generated gesture methods to operate *Chetna*. *Pointing* was used to select preferred choice from system provided options, whereas *horizontal arm swipe (right-to-left)* & *horizontal arm swipe (left-to-right)* were used to navigate across *next* and *previous* health information respectively. A visual aid in form of a hand cursor acted like on-screen cursor for pointing. By performing *bringing two arms together* gesture anywhere during the interface activated the menu where major categories of health information were displayed. Similarly, r*aising any arm above head for 2 seconds, halt with & without arm stretched* and *Come back-I* (Come back gesture with forearm in upwards direction) were extracted to perform anytime during the interface to request *help*, *pause* and *resume* respectively. Visual representation of each gesture is shown in figure 16 in section 4.3 in previous chapter.

4.5 Protocol for system interaction and navigation

Chetna is a gesture enabled TV based health information system to educate PW about pregnancy and related activities. This section presents a structural navigational flow of *Chetna.* Step-by-step stages, system contents, gestures and related feedback is showcased here.

Chetna consists of 3 major design components: User authentication and login, interactive training module and maternal health information dissemination. Information architecture and navigational flow of S&R in *Chetna* is presented in figure 25. The information architecture and navigation flow for FH and T&C is same as presented for S&R. This is followed by detailed explanation of the proposed 3 design components.

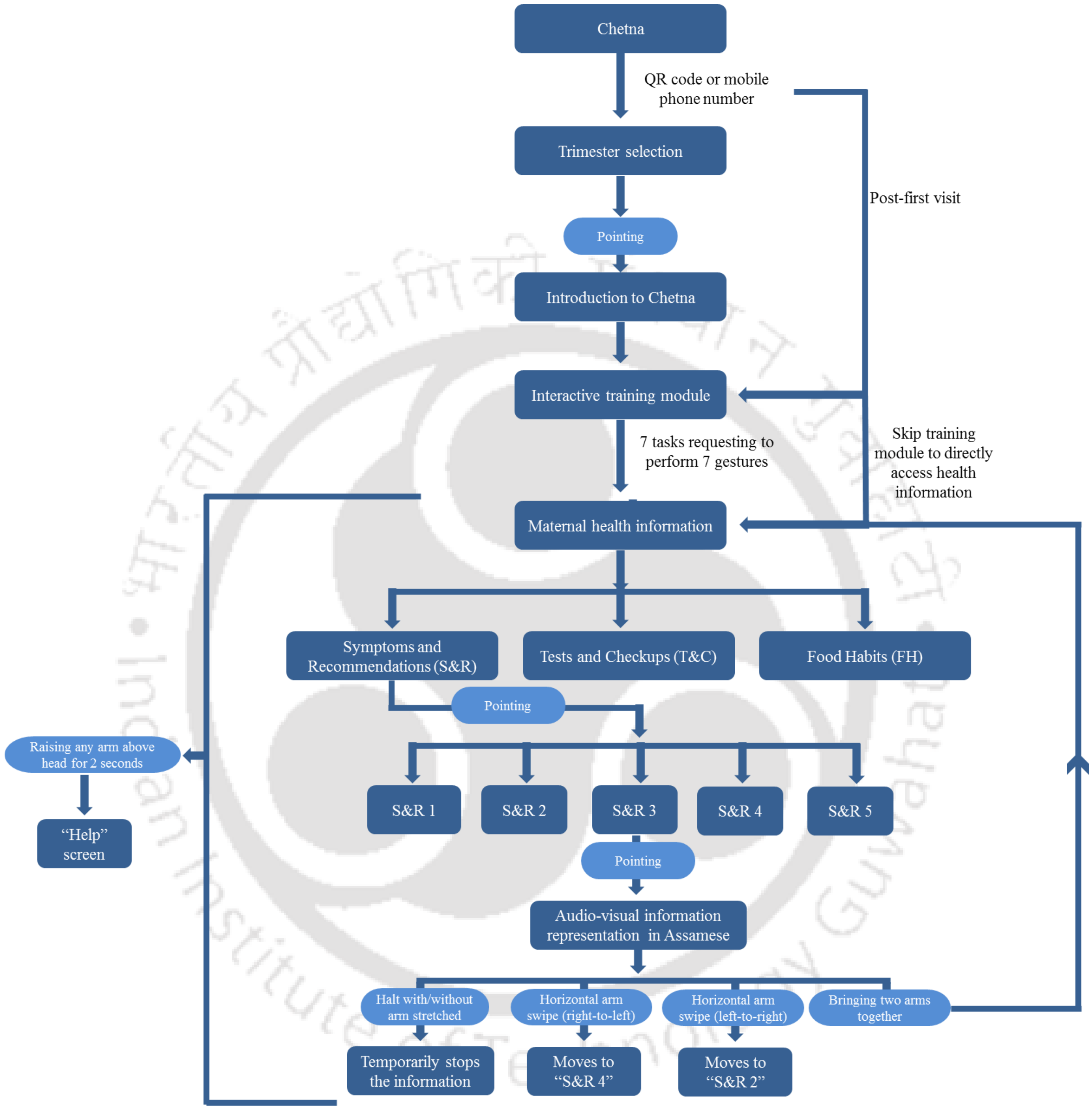

Figure 22. Information architecture and navigational flow of S&R in *Chetna* health information system

4.5.1 *Step 1: User authentication and login*

In order to provide customized health information, *Chetna* authenticates users through a unique identification number. In this case, a mobile phone number or unique QR code is used to authenticate users. System detects user's presence and instructs to call on a given number through her mobile phone or to show a QR code towards Microsoft Kinect. QR code is given to PW who did not have a mobile phone. Figure 26 showcases QR code given to the users. Each user is asked to enter relevant trimester information by pointing towards the trimester numbers presented on screen. Figure 27 showcases a screenshot of trimester selection interface. Users visiting the system more than once need not to enter the trimester information for each visit. User authentication and trimester selection helps identify the user to provide new maternal health information for her subsequent visits.

Figure 23: QR codes with unique identification number and *Chetna* logo

Figure 24: A screenshot of a trimester selection interface

4.5.2 *Step 2: Interactive training module*

Users are briefly introduced to the aim of *Chetna* followed by interactive training of gestures to operate the system. An avatar of ASHA who is virtually present in the system introduces the system and explains its aims and objectives. Further, all seven gestures are one-by-one explained through audio-visual demonstration to each user. The sequence of demonstrated gestures are *Pointing (Select), Halt with & without arm stretched (Pause), Come back-I (Resume), Horizontal arm swipe right-to-left (Next), Horizontal arm swipe left-to-right (Previous), Bringing two arms together (Activate Menu) and Raising any arm above head for 2 seconds (Help)*. The demonstration is given by virtual ASHA. After the demonstration and explanation of each gesture, users are given a task to perform the demonstrated gesture in order to increase the familiarity. To demonstrate *Pointing* gesture, virtual ASHA explains, “To choose any information, you should point (by providing visual demonstration of *pointing* herself) at content presented on the screen. Now try to select the information presented on your screen (task given to users)”.

Encouraging feedback is given to users if gestures are performed accurately. For instance, “wow, very good. You have performed the gestures correctly. Now let's go to another function that helps you *Pause* ongoing information". If users perform gesture inaccurately, the gesture is re-explained to users. For instance, "No, not like this. You should *Point* (by providing visual demonstration of *pointing* herself) at content presented on the screen". The interactive training module is mandatory for first time users. For further usages, the training module is kept optional and allows users to skip the training module. Figure 28 showcases a screenshot of virtual ASHA giving a task to perform *Halt* gesture for *Pause* function.

Figure 25. A virtual ASHA demonstrating a task to perform gesture for *Pause* function

4.5.3 *Step 3: Health information dissemination*

Users are given customized health information relevant to their trimester. Categories of S&R, T&C and FH are presented to users after a training module. The details of maternal health information categories are presented in sections 5.2.1, 5.2.2 and 5.2.3. Virtual ASHA explains each category of health information along with the contents expected under those categories. She also demonstrates and explains the *Pointing* gesture in order to choose any of those categories. Users are allowed to choose any health information tailored to their trimester. Figure 29 showcases an interface screenshot of virtual ASHA demonstrating health information categories.

Figure 26. Interface screenshot of "main menu" presenting health information categories of S&R, T&C and FH

Post selection of information category, each content under the chosen category is explained verbally by virtual ASHA. The verbal communication is supported by highlighting the icon of each content. Users can get suitable health information by selecting any preferred health icon presented on the screen. Chosen contents are presented in two phases. First phase verbally introduces the information followed by visual presentation by an avatar of PW. For example, explanation of upset stomach is verbally introduced by avatar of ASHA first, followed by an avatar of PW enacting problems faced during stomach upset as shown in figure 30. One question is asked after each information is demonstrated in order to confirm their understanding and learning. Two options for each question are given which can be selected through *Pointing.* A successful answer of asked question leads to motivated system feedback, whereas a wrong answer is reverted back with explanation of correct answer.

Figure 27. A screenshot of an avatar of PW enacting the symptom of upset stomach

Once the information is completely demonstrated to users, all possible interactions and associated gestures e.g. *Next, Previous & Activate Menu* are explained and demonstrated to the user for further navigational help. *Next* and *Previous* functions lead to next and previous information respectively whereas *Activate Menu* navigates user to home screen where health information categories are presented. An option to restart the same content is also present incase users want to re-learn about the same information.

Health information for each category of each trimester is presented with similar interface and navigation flow to maintain consistency across the interface.

4.6 System implementation

Chetna consists of three main processes: Microsoft Kinect™, graphics engine and application core logic. Microsoft Kinect™ is used to track users' body movement. It tracks user joints in 3D coordinate space and upper body joints were used to detect and track all gestures. The backend is coded in C# utilizing Microsoft Kinect™ SDK 1.7. MySQL was used to generate the database where data such as user number, trimester information, number of visits, total time spent, number of performed gestures and details of information viewed were recorded for future analysis. User authentication is triggered when user calls a particular number or shows QR code. A QR code is identified using the Microsoft Kinect™ camera. The system is serially connected to a phone, which then cuts the call and obtains the user's phone number through caller ID. Throughout the system, the user is identified through her phone number or QR code number. Maya animation software was used to create 3D animation for designed avatars and for information communication. The animations were further video rendered to code in the SDK. System architecture for *Chetna* is illustrated in figure 31.

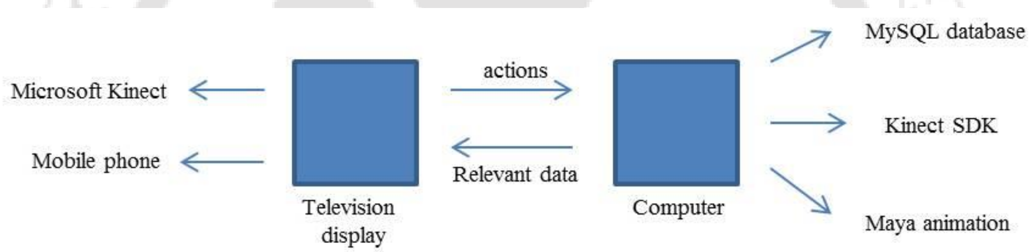

Figure 27. Technology setup and architecture of *Chetna*

4.7 Research questions

This chapter introduced *Chetna* - a gesture enabled maternal health information system in order to create awareness and educate PW of rural Assam in India. The system is carefully designed where it accommodates socio-cultural and geographical factors influencing the acceptance of such system in rural areas of Assam. The proposed information system uses body-gestures as input modality to operate technology supported information system which is a rarely explored modality of interaction among the targeted user group of rural PW. Although gestures are one of the most natural modes of human-human communication, it is rarely explored in the context of HCI research among users of resource scarce regions in developing countries. Therefore, it is important to understand the acceptance of gestural interfaces among rural areas of developing countries. This is further extended to investigate learnability of a new interaction modality of body-gestures, if such systems are deployed for a longer duration.

Hence, following research questions were identified in order to investigate the acceptance of a gestural information system of *Chetna* and effectiveness of body-gestures as input modality among the targeted user group.

- Does the information system of *Chetna* find acceptance across PW of rural Assam?
- Do learnability of body-gestures as interaction modality increase over time through subsequent visits to *Chetna*?
- What preferences and challenges do users face while interacting with the information system, especially when users have no previous experience using gesture-based interaction systems?

Chapter 5

Experimental Investigation of Gesture-based GUI

In order to investigate the hypothesis, an experimental investigation was done in a form of on-field pilot study at local health centers in rural Assam in India. Considering the research being applied in nature, the field validation and open activities could help provide on-field realities for acceptance of such systems (Gutwin and Greenber, 1998; Oulasvirta, 2011). Details of the study, methodology, participants, protocol and data collection methods are elaborated in this chapter. It starts with providing an overview of the field trials followed by details of PW participated in the study. Procedure and methodology for data collection is explained in sections 6.4 and 6.5 respectively. Material and apparatus used during the pilot study is elaborated in section 6.6.

5.1 Research objectives

Two research questions were verified based on our research objectives focusing on system's acceptance and learnability of body-gestures as interaction modality.

Objective 1: To investigate users' acceptance of gesture controlled user interface in terms of usability, usefulness, physical stress and behavioral intention

Objective 2: To investigate gesture learnability over time through subsequent system visits of users from resource scarce regions

5.2 The study location

The validation study aimed to investigate system acceptance, gather data to investigate gesture acceptability and learnability and interface usability for gesture enabled TV based health information dissemination system of *Chetna*. It was conducted in two phases in which the system was deployed at two different locations for the duration of 2 months each. For the first two months, *Chetna* was deployed at village Bonmoja mPHC and Dhupatri sub-center (SC) at Changsari, approximately 30 kms away from Guwahati. These centers cater to an approximate population of 30,000 people. The health centers were remotely located and had very limited transportation facilities available to commute. The common modes of commuting were personal vehicles and local auto rickshaws. No bank ATMs were available in the vicinity of 2 kms. Bonmoja mPHC consisted of 6 small rooms and one 5 bedded large room (for medical checkup of patients). An adequate space in a room of health center was allotted by the medical officer for setting up the system for trials. Setup location of Bonmoja mPHC is shown in figure 32. Second location was village Moriypatti SC located around 12 kilometers north from Guwahati covering a population of approximately 10,000 people. The population of this location had relatively higher access to ATMs and was also relatively better access to Guwahati city through busses, auto rickshaw and other modes of transport available for commuting.

Figure 29: Setup of pilot location I, Bonmoja mPHC

Chetna was kept for field trials at these health centers. It was open to visitors for interaction between 9 a.m. to 5 p.m. To enable continuous access to patients, family members, visitors and health center staffs, the setup was located in an open space at these health centers for the study. Official permission was given for the study for a period of 2 months at each of the health centers.

5.3 Participants

The system was deployed in 2 different locations over a period of 4 months for participants whenever they wanted to visit and interact with the system. Instead of following traditional procedures of recruiting participants and to ensure the maximum understanding of on-field trials, the system was made available to ASHAs and PW to visit and use on their convenience. The initial intention of participant selection was to visit every PW's household to invite them to the system, however it was found very difficult as health centers and ASHAs did not have an accurate database (e.g. address) of all PW. Moreover, the distance of all PW was the other challenge for us to accommodate an invitation for each PW. Hence, ASHAs were invited to health centers in order to gather participants for the study. They were informed about the location of the system and were asked to invite PW to use during their routine checkup to health centers or during any other time they wished to visit. The system was catered to PW from all three trimesters, hence PW of all trimesters were invited to visit the system. ASHAs were also asked to inform women who were planning to extend their family in a near future. They were asked to be present with PW, invite them to visit the system for at least 3 times and act as moderator for the study.

No participants had any prior experience with gestural interfaces or had never participated in any such studies.

5.4 Procedure

Both locations followed same apparatus, methodology and protocol to gather feedback from participants. Prior to PW usage, ASHAs under each health center were introduced to *Chetna*. Further, they were asked to inform, invite PW and moderate the study without any constraints on visiting time. Details of the briefing sessions are presented below.

Briefing to ASHA: ASHAs of each health center were invited two days prior to the actual study to get familiar with the system. A brief discussion session was conducted to introduce aims & objectives, interactive training module, gestures and healthcare information dissemination. ASHAs were also invited to use and get familiar to the system in order to help participants for possible challenges faced during the study. They were clearly instructed not to perform a study on behalf of participants, but to assist them during the study. They were also asked to moderate each session due to their language preferences and existing social bonding with the participants.

Briefing to the participants: Moderators briefed participants about the purpose and features of *Chetna*. The briefing was done verbally in Assamese language and only during their first visit. Participants were encouraged to ask questions immediately for the problems faced during and after the study. Each participant was given an option to interact with the system in sitting or in standing position. They were encouraged to revisit *Chetna* for at least 3 times to collect all necessary information for healthy and safe pregnancy, however it was not made mandatory. For each health center, a briefing was done for initial 3-4 times and further participants started using the system without briefing. This happened due to internal community discussions about *Chetna*, hence participants were already introduced prior to its use.

Researchers were also present during the study, but they did not intervene during system usage. They mainly observed the behavior of participants and helped during technical problems. Video recording was done with permissions from participants and moderators. Camera was placed at a distance covering the side and back view in order to eliminate the hindrance and consciousness.

5.5 Data collection method

Participants and their usage statistics were collected with the help of a created database. The database provided information such as total number of visits by each PW, unique identification number collected through a mobile phone or unique QR code, trimester information, total time duration spent with the system, viewed information and a total number of gestures performed for each function. The database was used to further generate usage metrics for the system.

Technology Acceptance Model 3 (TAM3) proposed by Venkatesh and Bala (2008) was used to examine user acceptance of *Chetna*. TAM3 is a comprehensive integrated model addressing the need to understand how new technology interventions can influence the determinants of its adoption and use. TAM3 questionnaire is based on a theory to understand user acceptance of certain technology. The determinants of this model include Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Output Quality (OUT) and Behavioral Intention (BI), Computer Playfulness (CPLAY), Computer Anxiety (CANX), Subjective

Norm (SN) and many more. Although it was designed to adopt for an Information Technology (IT) system, this model has already expanded its outreach by investigating technology acceptance and adoption in different domains such as internet banking (Kesharwani and Singh, 2012), assistive social agents (Heerink et al., 2010), tele monitoring systems for healthcare professionals (Gagnon et al., 2010), gestural interfaces for older adults (Bobeth et al., 2012) and many more. Hence, to investigate the acceptance of gestural interface among the targeted rural PW, TAM3 model was adopted.

Relevant questions of TAM3 items were selected to reduce the amount of items asked repetitively and because of evaluating a system where many items did not apply. 4 constructs of TAM3 - Perceived Ease of Use (PEOU), Output Quality (OUT), Perceived Usefulness (PU) and Behavioral Intention (BI) were used to gain feedback on the acceptance of a proposed gestural interface. Five items PEOU1 – my interaction with the system is clear and understandable, PEOU2 – Interaction with the system does not require a lot of my mental effort, OUT1 – the quality of the output I get from the system is high, PU4 – system is useful in my job and BI3 – I would like to visit the system again, of above 4 constructs were utilized which were found relevant to *Chetna*. One more item, "Experienced Physical Stress (EPS) while performing body-gestures" was added to the list of 5 items identified from TAM3. This was added due to higher importance given on a body imposed physical stress experienced in gestural interfaces (Nielsen et al., 2004). TAM3 questionnaire was presented in a written format to participants post system interaction. 5 point semantic differential scale was used to gather participants' feedback. These questions were presented to participants by the researcher in native Assamese language. They were repeatedly requested to provide non-biased viewpoints and allowed to answer on their own. They were asked to answer on a printed paper written in Assamese language. In instances where participants did not know to read, they were asked to verbally state their feedback.

Subjective evaluation was conducted through observation of participants' interaction with the system. It was also done through detailed observation during physical presence at study location and through recorded videos of participants interacting with *Chetna*. Researchers observed participants, their behavior, preferences and challenges faced while operating the system.

5.6 Material and apparatus

A combination of laptop, TV and Microsoft Kinect™ was used to setup the field trials. A 42 inch high definition TV connected to a laptop was used to display maternal health information. The laptop acted as a control device with a dual 2.6 Giga Hertz (GHz) intel processor and 4 Giga Bytes (GB) of Random Access Memory (RAM). Laptop was kept hidden from the participants to provide a natural environment setup. Laptop was continuously switched ON and whenever participants visited health center, ASHAs switched ON the TV. *Chetna* logo was presented when TV was switched ON. Microsoft Kinect™ was placed on top of TV to detect full body gestures. A stand underneath to Microsoft Kinect™ was kept to provide better stability. A long extension board was always kept at the study locations with 3 electric connections as no study locations had more than one electric connection at one place. Chairs were surrounded to set-up for spectators to sit and view system interactions.

Chapter 6

Results and Discussions

Chetna - a gesture enabled health information system was deployed for a period of two months each at two different locations of rural Assam in order to investigate system acceptance and gesture learnability as input modality. This chapter reports quantitative analysis and subjective findings conducted to understand above parameters. This chapter starts with providing system usage statistics of *Chetna* in a form of participant metrics – total number of participants, age group, literacy; gesture metrics – total number of gestures, technical errors, participant errors; and information metrics – total number of information viewed, individual health information views. System usage metrics are presented in section 7.1 to provide an overview of system usage across 4 months in 2 different health centers in rural Assam. This is followed by the results of statistical findings supported by subjective analysis on system acceptance (section 7.2) and gesture learnability (section 7.3). Section 7.3 also correlates gesture errors to the type of gestures to further elaborate the findings on individual gesture learnability.

Qualitative findings identified through on-field observations are reported and further discussed in section 7.4. It starts with discussing influence of socially relevant design elements such as use of virtual ASHAs as persona and use of female gender to present maternal health information (section 7.4.1), impact of placement and reachability of interface icons and instructional approach to understand participants' interaction with proposed GUI design and information delivery (section 7.4.2). This is followed by section 7.4.3, where amplified gesture expressivity and variations in individual gesture performance observed among participants are reported and discussed. A spirit of collaboration among participants and spectators was observed in order to guide participants for better operability is reported in section 7.4.4. Influence of cultural elements, especially cultural clothing in rural Assam on accurate gesture recognition is discussed in technology limitations and challenges in section 7.4.5. Findings of field realities in a form of infrastructural challenges, socio-cultural constraints and influence of alien researchers and equipment experienced during field trials are elaborated in section 7.4.6. Finally, the last section of this chapter introduces guidelines to design gesture supported health information system suitable for low literate rural users of a resource scarce region. This may be adapted to meet the specific context of maternal healthcare among developing countries.

6.1 System usage metrics

Total 63 participants visited the system over a period of 2 months each at two different locations. Out of 63 participants, 36 visited twice and 13 visited the system three times. Total 2417 gestures were performed with 52 participant errors and 131 technical errors. Participant errors are errors that occurred due to participants' wrong performance of gestures e.g. performing a non-existent gesture or exchange of gestures to functions. Technical errors are errors due to technical limitations, e.g. false positive. Participant errors were gathered through observations during physical presence of researcher and viewing captured videos. Total 612 information were viewed with 339 S&R, 212 T&C and 66 FH. Figure [33 (a), (b), & (c)] presents metrics related to the participants' presence, performed gestures and information viewed on the system.

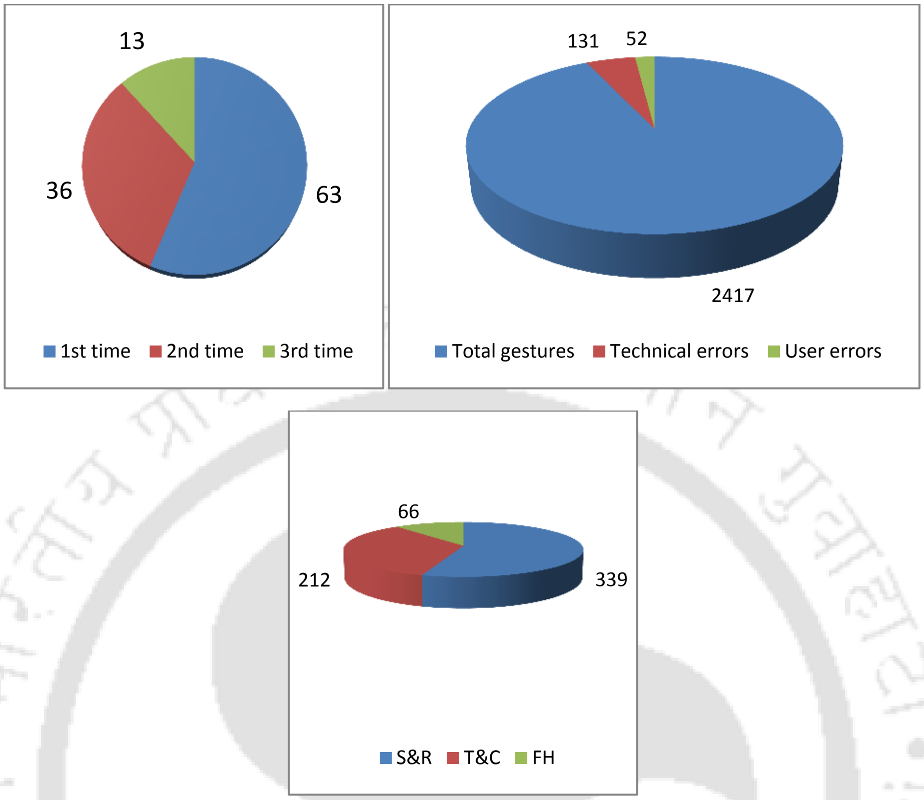

Figure 30. (a) Metrics of participants' visits to the system (b) gesture metrics (c) metrics of information viewed

6.1.1 Participants metrics

Over a period of 4 months, total 63 unique participants visited *Chetna* at two different study locations. The system was kept for two months at each location. Participants were PW enrolled under a health center of a specific location. All participants were housewives and followed Assamese as their native language. The mean age of participants was 25.2 years, with a range of 19 to 33 years old. Out of 63 participants, 3 were graduates, 30 were 10th or above grade, 27 were below 10th grade and 3 were completely illiterate. No participants had prior experience of using gestural interface, a computer and internet service and no prior experience of participating in such validation studies before. Only 21 participants had owned mobile phones and often used *calling* feature. Other participants either did not own a phone or used mobile phones of their husband or neighbors. Only 2 participants had used mobile phones to send messages. No participants had tried listening to songs or setting an alarm or used other advanced features on their mobile phones. They were familiar with using TV remote, mainly to change channels and increase/decrease volume.

The system was allowed to keep for two months due to government restrictions for deployment of external services for a maximum of 2 months. This included weekends, public holidays and non-working health center days. Non-working health center days included days when ANMs need to visit the CHCs for reporting data, trainings, meetings and new government initiatives. This was seen 3-4 times a month and during such instances, the health centers were closed.

Out of a total 63 participants, only 13 participants visited the system thrice. Multiple factors were observed influencing the revisits of participants to the system. Common factors such as an absence of ASHAs, husband-family member denials, traditions and festivals, local political dynamics and distance restricted multiple visits of participants in shorter time duration. ASHAs were responsible for various health diseases in her community which restricted their presence for maternal health once in a week, where other days were allotted for malaria, tuberculosis, institutional deliveries and other diseases and CHCs visits. An absence of ASHAs to accompany participants restricted their visits to often one visit or sometimes two visits in one week. Family members, especially husbands' work schedule also affected participants' visits. For instance, if husband is present at home, participants prefer to be present at home to cook food and take care of husband's daily necessities. In the month of January, a local festival "Magh-Bihu" restricted participants' and ASHAs presence for 10 days. This is mainly due to time required for preparation of the festival, as it was a traditional festival of Assam. Similarly, a local festival of "Bohag-Bihu" restricted participants' and ASHAs presence for 10 days in the month of April. These restricted active system usage and interaction to a total of 16 days.

Out of 17 participants of 3rd trimester, 10 visited the system twice and none visited for 3rd time. This is mainly due to a local tradition where 3rd trimester PW were not allowed to go out of their home before 20-25 days of due delivery date. 15 participants could not visit the system due to unavailability of local transport to health centers which were 4-6 kms distant from health centers. Hence, they did not revisit the system for 3rd time. However, 8 of them visited the system twice with insistence of their ASHAs. One ASHA did not bring her PW after their 1st visit due to local dynamics with other ASHAs. She believed that she being a senior health worker, her PW should be given priority. Hence, she did not re-invite her 9 PW to visit the system post one time usage. 5 participants who visited the system twice did not visit 3rd time citing the reasons of family members' denial, unavailability of time and bad health. 4 participants who visited system once did not revisit as they moved to their mother's home for better preparation of pregnancy. Overall, 36 and 13 participants visited the system twice and thrice respectively.

Following sections provide comparative evaluations for participants who visited the system thrice (n=13) to ensure their progressive usage over the course of system deployment. It provides the evaluation of system usage, acceptance and gesture learnability for subsequent visits.

6.1.2 Information metrics

Total 612 health contents were viewed over 112 visits to the system. This was further categorized in 339 S&R, 212 T&C and 66 FH. Figure 34 presents details of viewed information over 112 visits. It was observed that information related to the stomach and lower abdomen was often viewed by participants. S&R such as heartburn, constipation, stretch marks, fetal movement and upset stomach and T&C such as urinary test, ultrasound test and HB test were viewed relatively higher number of times. Ultrasound and urinary tests were recently introduced in government services, which could have caused its high access by participants. Health information such as piles, sleeping habits, contraction, overdue date, breathing problems etc. was relatively less viewed by participants. This could be mainly due to such symptoms being less experienced by PW. Calcium rich food was preferred over other food habits. FH were viewed relatively less as they were uploaded at later stages of the study due to higher time consumption in 3D animation & rendering.

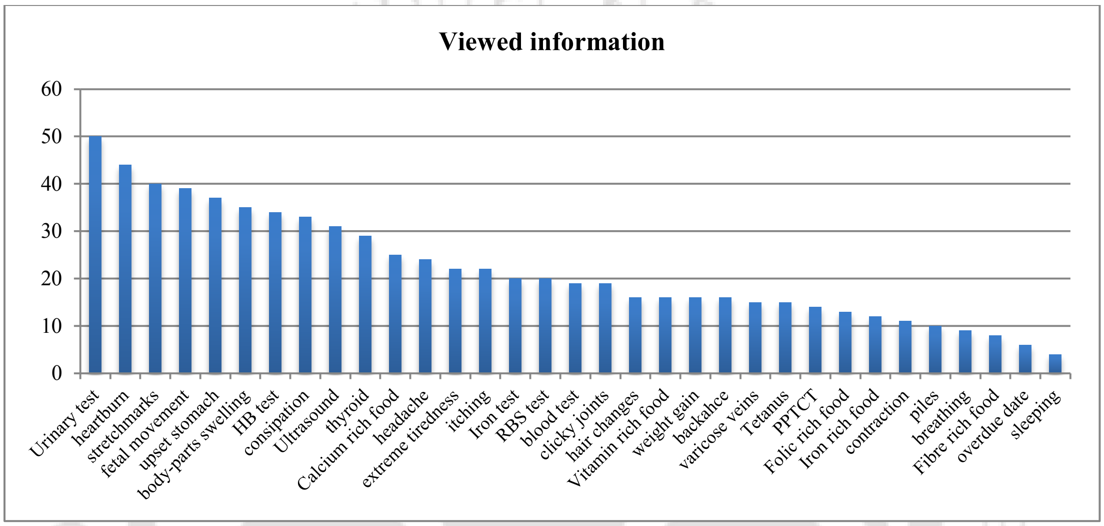

Figure 31. Category of information viewed over a period of 4 months in 112 visits

These findings provide a strong basis for designing suitable information architecture for similar maternal health information systems where most viewed information such as ultrasound, urinary test, constipation, heartburn etc. can be made high priority information and can be presented with increased importance. This further expands the scope to design better information architecture for training modules for health workers in resource scarce regions.

6.2 System acceptance metrics

6 questions were asked to participants to investigate user acceptance. The questions were adapted from 4 constructs (e.g. PEOU, OUT, PU and BI) of TAM3 and EPS which were further modified according to our context to ensure its

relevance to understanding participants' acceptance of the system. A 5 point semantic differential scale (1-strongly disagree and 5 – strongly agree) was presented to participants to gather data of 6 constructs (e.g. PEOU1, PEOU2, OUT1, PU4, BI3 and EPS). The results are presented through descriptive statistics (mean and standard deviation (SD)) of TAM3 questions in Table 4 and 5. Table 4 presents combined responses of 13 participants over 3 visits, analyzing total 39 records. Table 5 describes mean & SD values of 13 participants for each visit. The results are indicative of a system being accepted across the targeted user group of rural PW. Overall, experience of interacting with the system was found very clear and understandable and required very less mental effort indicating a higher perceived ease of use for the participants (PEOU1 – mean=4.51, SD=0.60; PEOU2-mean=4.33, SD=0.57). Clear understanding was also influenced by higher quality output from the system felt by participants (OUT1-mean=4.41, SD=0.85). Information was also found very communicative and useful to the participants strongly agreeing to perceived usefulness of the system (PU4-mean=4.31, SD=0.69). Concerning the acceptance factor of behavioral intention, the results indicate higher intention to use gestural interfaces among low literate users (BI3-mean=4.72, SD=0.56). Moreover, gestures identified through a user generated gestures approach were not found demanding physical stress (EPS-mean=4.62, SD=0.59).

No.	PEOU1		PEOU2		OUT1		PU4		BI3		EPS	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1st visit	4.51	0.60	4.33	0.57	4.41	0.85	4.31	0.69	4.72	0.56	4.62	0.59

Table 4. Descriptive statistics of 39 responses representing 3 visits of 13 participants

No.	PEOU1		PEOU2		OUT1		PU4		BI3		EPS	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1st visit	4.5	0.64	4.66	0.47	4.75	0.43	4.42	0.49	4.25	0.59	4.75	0.43
2nd visit	4.66	0.47	4.58	0.49	4.41	0.64	4.25	0.72	4.58	0.49	4.91	0.27
3rd visit	4.5	0.64	4.75	0.43	4.58	0.86	4.5	0.64	4.75	0.59	4.91	0.27

Table 5. Mean and SD of acceptance values of the applied TAM3 items for 3 subsequent visits of 13 participants

Null hypothesis 1: There is no significant difference in 5 constructs (e.g. PEOU1, PEOU2, OUT1, PU4, BI3 and EPS) of system acceptance over subsequent 3 system visits

Paired sample t-test was conducted for a significance value of 0.05 to compare differences of opinion for 3 subsequent system visits of defined 5 constructs. No significant differences were observed for PEOU1, PEOU2, OUT1, PU4 and EPS between 1st and 3rd visit (PEOU1 – p=0.83; PEOU2 – p=0.28; OUT1 – p=0.95; PU4 – p=0.66, EPS – p=0.19) and between 2nd and 3rd visit (PEOU1 – p=0.67; PEOU2 – p=0.75; OUT1 – p=0.31; PU4 – p=0.62, EPS – p=0.51). However, the study observed a significant difference for BI3 between 1st and 3rd visit ($p = 0.001$, $p < 0.05$) and between 2nd and 3rd visit ($p = 0.001$, $p < 0.05$). Hence, the null hypothesis for 4 constructs (e.g. PEOU1, PEOU2, OUT1, PU4 and EPS) is accepted and BI3 is rejected.

The results indicate that the constructs (e.g. PEOU1, PEOU2, OUT1, PU4 and EPS) related to usability were found consistent across the visits among participants. All participants found it equally usable and useful for all the visits. Significant differences in BI3 demonstrate an increased willingness to revisit the system after 2nd visit, indicating a strong acceptance and willingness of using such systems.

The study also measured if the acceptance of the system varied with a different age group of participants.

Null hypothesis 2: There is no significant difference of opinion of participants on 5 constructs of system acceptance corresponding to different age groups of rural PW

One way ANNOVA with a significance value of 0.05 was used to measure the differences of opinion for all constructs across a varied age group of participants. The results present no significant difference for all 5 constructs (PEOU1 – p=0.64; PEOU2 – p=0.225; OUT – p=0.572; PU – p=0.246, BI – p=0.306; EPS – p=0.067) across all the age groups of participants. Therefore, the null hypothesis is accepted which further reveals that perceived ease of use, output quality, usefulness, behavioral intention and physical stress was found consistent across all age groups of PW during the field trials.

6.2.1 Findings of field observation on system acceptance

On-field observations demonstrated increased curiosity, willingness, familiarity and interest in using *Chetna* across the participants. For example, a participant who visited the health center (for a routine checkup) denied to use the system stating that, "My health is perfectly fine and I am not ill, so I don't want to use it (*Chetna*)" considering the system as equivalent to a doctor. Participants also started questioning and recommending symptoms they experienced during pregnancy. A participant during her second visit recommended the moderators that, "I feel itching all the time, but there is no information on how to reduce itching. Can you help me with that?" Calls from ASHAs of other local communities were received requesting to educate their PW too. One ASHA stated that, "You are giving the system to PW of other local ASHAs, we also want our PW to get benefitted, hence please inform me when should we come". Such calls and competition among ASHAs demonstrated wider reach, curiosity and acceptance across the community. Participants also showed confidence to visit health centers without the presence of ASHAs. This was observed mainly in 2nd and 3rd visits. ASHAs use to inform participants to visit the system at a given time and often observed with her delayed visit to the system. For instance, one ASHA was found absent due to an emergency institutional delivery; however participants were present to use the system. Increased participation of community members and family members of participants was also observed during the study. Husbands and mother in-law started accompanying the participants during their health center visit. This happened mainly in the case of 2nd and 3rd visit of participants.

Attention and curiosity was gathered across non-PW too. Due to system's presence in publically located health centers, a lot of non-PW keenly observed and waited to operate it. For instance, one adolescent girl (who came with her parents) requested her parents to allow her to use the system. On approval, she used the system for 20 minutes, listening to all pregnancy related information. She also asked whether the system is always available in health center and whether everyone is allowed to use the system. Similarly, one elderly male (who visited health center for the checkup of cold & fever) curiously asked moderators about the system and requested them to operate it. He used the system considering it helpful that this information will help his children and also help him exercise as it performed body movements.

6.3 Gesture metrics

Performance of gesture errors across 3 visits was measured to investigate gesture learnability among the targeted user group. As total 13 participants revisited the system thrice, hence this analysis is conducted for 13 participants. Overall, gesture errors across all visits were found very low with total 52 errors in 111 visits. This indicates less than half error in each visit. Difference in total gesture errors and individual gesture errors are explained in following section.

6.3.1 Learnability of body-gestures

Null hypothesis 1: There is no significant difference in learnability of gestures corresponding to the number of system visits

ANNOVA was conducted with a significance value of 0.05 to investigate an increase in gesture learnability to the number of system visits. The results indicate that there is no significant difference in the number of errors to subsequent system visits ($p=0.56$). It reveals that there is no increase in learnability of body-gestures over subsequent system visits by the participants. Although, non-significant difference was identified in gesture learnability, the descriptive statistics presented in table 6 demonstrates overall decrease of gesture errors between 1st and 3rd and 2nd and 3rd visit. Therefore, the null hypothesis is accepted indicating no increase in learnability of body-gestures over subsequent visits.

Visit no.	Mean	SD
Visit 1	0.952	0.5728684
Visit 2	0.1190	0.4500384
Visit 3	0.0476	0.2142484

Table 6. Mean and SD value of gesture errors for three subsequent visits (n=13)

Null hypothesis 2: There is no significant difference in the gesture errors corresponding to the type of gesture

ANNOVA was conducted for a significance value of 0.05 to investigate the influence of different gestures on gesture errors. The results reveal a significant difference in gesture errors to the types of gestures ($p = 0.05$). This rejects the null hypothesis and indicates that gestures errors were not consistent for all individual gestures, where few had relatively high number of errors. Descriptive statistics, presented in table 7 also demonstrates that gestures of computational function *Help, Next* and *Activate Menu* had maximum errors followed by *Previous* and *Pause.* No errors occurred while performing gestures for *Select* and *Resume* functions.

Type of gesture	**Mean**	**SD**
Select – Pointing	0	0
Help – Raise hand for 2 sec.	0.28	0.18
Activate Menu – Bringing two arms together	0.11	0.39
Next - Horizontal arm swipe (right-to-left)	0.16	0.56
Previous - Horizontal arm swipe (left-to-right)	0.03	0.17
Pause - Halt with & without arm stretched	0.03	0.17
Resume - Come back-I *(*Come back gesture with palm in upwards direction)	0	0

Table 7. Mean and SD value for 7 different types of gestures (n=13)

Due to a significant difference in gesture errors corresponding to types of gestures, further analysis was attempted to see the variance in learnability with individual gestures corresponding to the number of visits. Paired sample t-test was conducted to investigate learnability of individual body-gestures to the number of system visit. The significance value for this analysis was taken 0.05. The results reveal a significant difference for gesture of *Pause* function between 2nd and 3rd visit ($p=0.039$), gesture of *Previous* function between 1st and 2nd visit ($p=0.03$) and 2nd and 3rd visit ($p=0.03$) and gesture of *Help* function between 1st and 2nd visit ($p=0.01$). No significant difference was identified for gestures of other functions for 3 subsequent visits.

The results indicate individual gesture learnability for gestures of *Help, Previous* and *Pause* function whereas gestures of *Select* and *Resume* function was performed without any errors. Although, the learnability for gestures of *Activate*

Menu, *Next* and *Help* function was identified non-significant, the results are indicative of these gestures being easy to learn and use. Figure 35 shows gesture errors in *Activate Menu, Next* and *Help* for subsequent visits.

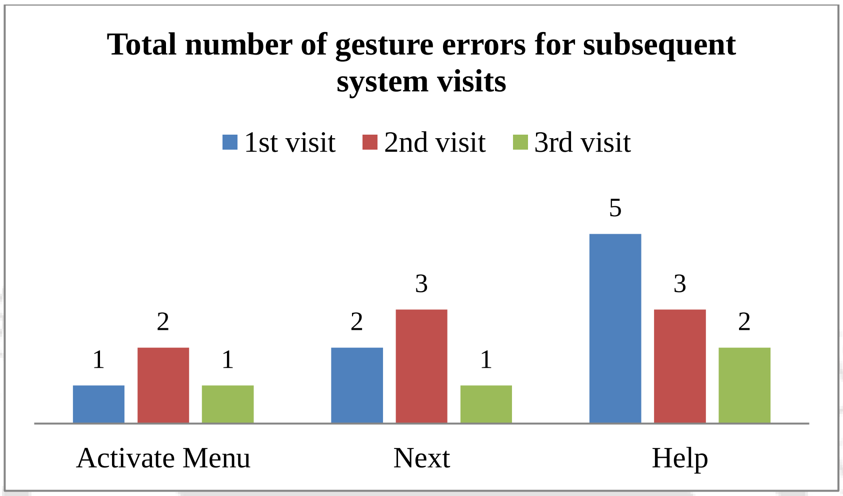

Figure 32. Gesture errors of subsequent visits for *Activate Menu, Next* and *Help* function (n=13)

Another interesting inference of the results reveal that gestures with higher constraints in a defined direction of performance and dependent of specific body-part (e.g. activate menu and help) showed a relatively higher number of errors. For instance, a gesture of *Activate Menu* required both hands to be swiped above the stomach and below the chest to eliminate false positives. Similarly, gesture of *Help* demanded participants to raise the hand for minimum 2 seconds, where many participants removed it before 2 seconds. Gestures that demanded least restriction in range-of-motion and direction were found with least errors. For example, gestures of *Pointing (Select)* and *Come back I (Resume)* was performed without any restrictions of directions and any attachment to specific body parts.

Overall, there was a significant difference identified in learnability of individual gestures of *Help, Previous* and *Pause*. Although it was not observed significant consistently for all the visits, but it was observed after 2nd system visit.

Moreover, the gestures of *Activate Menu*, *Next* and *Help*, which did not find significant learnability, was indicative of increased learning of gestures through less errors performance in subsequent system visits. The current evaluation faced challenges of limited 2 locations and limited time durations with limited dataset of only 13 participants using the system thrice. Scaling up the system for multiple locations and longer duration may result in increased number of participants visiting the system multiple times which may help in quantifying the effect with a statistical confidence.

6.3.2 Findings of field observations on gesture learnability

Non-significant difference in gesture errors was identified in subsequent visits among participants. During first visit, participants were asked to mandatorily perform training module, whereas in 2nd and 3rd visit training module was kept optional. It was observed that, in 2nd and 3rd visits, participants directly attempted to access the system information and often skipped training module. This caused increased gesture errors across few participants, especially during 2nd visit. For example, 3 continuous errors were made by one participant while performing *Help* function. Figure 36 shows a participant performing incorrect gesture for *Help* function. Instead of raising her hand above head, she kept raising her hand till her shoulder. Similarly, few participants performed *Next* function by swiping their hand below the stomach which caused errors. Figure 37 shows one of the participants performing *Next* below her waist.

Figure 33. Participant raising her hand till shoulder to perform *Help* function (the image is extracted from a recorded video)

Figure 34. Participant swiping her hand below stomach to perform *Horizontal arm swipe (right-to-left)* for *Next* function (the images are extracted from a recorded video)

This is mainly because participants who visited the system 2nd time were still relatively new the system along with performing gestures without training. Moreover, the time duration between two visits was also inconsistent which may have influenced the gesture performance. Relatively fewer gesture errors were observed during 3rd visit over 1st and 2nd visit. This is mainly due to increased familiarity and confidence with gestures, at least two gesture performances and overall system usage. The inconsistency in gesture errors over 2nd and 3rd visit is still unclear and opens a new scope of research to investigate memorability of gestures.

6.4 Observations and discussions

The data collection gathered through video recording and field observation revealed important parameters which influenced the usage, acceptance and effectiveness of *Chetna.* It also revealed a variety of use of body-gestures as interaction modality. Although, these observations do not report statistical data but it certainly emphasizes on critical design elements for contextually appropriate design of gestural systems in resource scarce regions.

This section reports and discusses the findings of field observations gathered during the validation study. It starts with reporting the influence of socially relevant design elements in balancing human-machine interactions to human-human interactions. It elaborates the findings of using ASHAs as persona and use of female characters in reducing the gender gap for information dissemination (section 7.4.1). This is followed by section 7.4.2, where observations in ease of content selection and understanding due to icon placements and mode of instructional navigation in *Chetna's* GUI is reported and discussed. Observation in gesture performance in form of expressiveness and variations are discussed in section 7.4.3 followed by and impact of participatory interaction with the information system in section 7.4.4. Technical limitations and challenges resulting in accurate gesture recognition are explained in section 7.4.5. Further, field realities experienced during the validation study and its impact on research is elaborated in the last section. It reports findings of geographical-social-cultural challenges and impact of foreign researchers and equipment on scientific research experiment.

6.4.1 Impact of socially relevant design elements

A virtual avatar of ASHA, use of female characters in visually demonstrating the information and familiar elements of traditional home and healthcare context was included in the design of *Chetna.* It was done based on the findings identified during the contextual inquiry to increase familiarity of the system and avoid an alien outlook to the system. Inclusion of these socially relevant elements had shown positive response from the participants. Following sections describe the effective usage of virtual ASHA as persona and familiar characters on participants' behavior.

6.4.1.1 Virtual ASHAs as persona

Appropriate usage of influential personas has proven effective in ICTDs in prior research (LeRouge et al., 2012; Ramachandran et al., 2010). Similar findings were observed for this study. Overall, use of virtual ASHA as persona for health information dissemination and navigational instruction had shown positive response across participants. It was observed that participants carefully listened to instructions and followed them as suggested. They were found continuously nodding their head in affirmation to health information and navigational instructions provided through the system. This benefitted in effectively communicating appropriate navigation and reduced confusion and hesitation in operating the system. It also benefitted in building respect and belief for *Chetna*. For instance, one participant removed her footwear (sleepers) when she saw the persona for first time. She even performed Namaste (greeting gesture) when the persona welcomed her to the system. Similar findings of greeting the persona with Namaste were observed across many participants during the study.

This expands the scope of using socially influential people as personas beyond a mere mediator to understand end-users and as a motivational element in ICTD systems. This clearly demonstrates an opportunity to use personas to help efficiently navigate across new technology systems, especially for novice users with low technology exposure and low literacy in resource scarce regions. Socially influential people as personas also present a potential to develop trust, high regards and respect to the systems disseminating culturally sensitive information (e.g. maternal healthcare, menstruation, tuberculosis etc.), especially for ICTD systems used in public spaces.

6.4.1.2 Gender supported acceptance

Use of female actors to visually demonstrate the health information observed acceptance among participants. Culturally sensitive information demonstrating influence on lower body parts (e.g. urinary infection etc.) were viewed without any shyness. They listened to complete information without any hesitation or embarrassment. This was observed even when many participants were sitting together and viewing the information.

However, influence of contextually familiar elements (e.g. bamboo house, Jhapi etc.) could not be validated as no participants ever discussed about it. The study also observed a challenge where presence of a male gender interrupted the focus of the study. Participants looked at each other and hesitated when a male member was present and viewed the system. Although, impact of their presence could not be measured as the participants continued to use the system, but it certainly opens the door for future scope of research. Gender biases in adoption of technology and different ICT platforms are often discussed (Dholakia et al., 2004; Celik and Ipcioglu, 2007; Ziefle and Schaar, 2011), but impact of gender issues in successfully delivering gender specific and culturally sensitive information can be further researched upon.

6.4.2 GUI design and information delivery

The design components of GUI of the system promoted ease of information selection and understanding. This section presents findings on how users perceived and interacted with designed graphical interface. Details are icon placements, selection and influence of instructional navigation is presented in following section.

6.4.2.1 Selection, reachability and placements of icons

Easy selection of icons placed at a center of the interface was observed during the study. Icons which were centrally aligned presenting health information contents, trimester selection etc. were found easy to select through pointing whereas icons placed in corners (e.g. skip training module, replay information etc.) were difficult to map and select for users. For example, one user could not effectively locate the "skipping of training session" and completed after 2 unsuccessful attempts. Replay icon was never attempted during the demonstration of information by participants. Moreover, selection of icons placed in corners took relatively longer time to locate and select. These findings are contradicting the findings proposed by Fitts (1992) where corners are infinitely targetable and accessible. Although, these are qualitative findings and do not propose any significant statistical data, but certainly opens a scope of research to investigate the need for different approaches to design GUIs for gestural interfaces.

6.4.2.2 Instructional approach to system navigation

Instructional approach to learning and discussion was commonly observed in day-to-day interactions among ASHAs and PW. Similar approach adapted to *Chetna* demonstrated increased attention and following among participants. Instructions given at every stage (to demonstrate next possible gestures/navigation or actions) helped participants seamlessly interact with the system irrespective of their number of visit. For example, instructions to perform *Next* given to participants after each information demonstrated, they preferred performing *Next* often to move across healthcare contents instead of performing *Previous, Replay* or *Activate Menu.*

The continuous set of navigational instructions sometimes resulted in complaints of unwanted repeated instructions, especially when the health information was shorter than navigational instructions. Moreover, it was also observed unwanted for participants visiting the system 3rd time, as they seemed to be familiar with the system. Participants visiting 3rd time did not wait for navigational instructions, but performed the gesture before the instructions are demonstrated. Overall, instructional approaches to system navigation aided participants in effectively interacting with the health information system, in some cases it was also observed unwanted, especially for participants who visited the system 3rd time. A study investigating the effectiveness of instructional approach with respect to the system familiarity in gestural interfaces could help derive new guidelines in effectively supporting in system navigation for novice users of resource scarce regions.

6.4.3 Gesture expressivity and variations

The study observed performance of loud and expressive gestures and demonstrated wide variations in gesture performing style by participants while operating *Chetna*. Gestures which are expressive often have publically noticeable effects of input gesture and the system feedback and are socially acceptable (Montero et al., 2010). Although the validation study of *Chetna* did not aim to investigate social acceptance of gestures, but found enhanced use of expressive gestures to interact with a proposed gestural interface. Participants were found performing loud and expressive gestures to initiate interactions for the system. They performed gestures more expressive than demonstrated in a training module in order to ensure its accurate detection. For example, gesture to trigger *Resume* function was initiated from the hips to touching the shoulder by most participants. Figure 38 shows a participant initiating the gesture from the hips to touching the shoulder to perform gesture for *Resume* function. Similarly, gestures for the functions *Next* and *Previous* were performed extreme beyond the stomach. Figure 39 showcases a participant performing *Horizontal arm swipe (right-to-left)* extreme beyond her stomach to activate *Next* function. Moreover, these gestures were performed very slowly as they believed by performing them slowly will increase the chances of its detection.

Figure 35. Participant performing an expressive *Come back-I* to initiate *Resume* function (the images are extracted from a recorded video)

Figure 36. Participant's hand moving extremely beyond stomach to perform *Horizontal arm swipe (right-to-left)* to initiate *Next* function (the image is extracted from a recorded video)

Multiple variations of same gestures were also performed by users. For example, gesture for *Activate Menu* function was often performed like "expressive Namaste" by participants (figure 40). Similarly, gestures for *Next* and *Previous* functions were performed with horizontal movement over the chest to lower abdomen.

Figure 37. Two different participants performing *Bringing two arms together* (Activate Menu) like "expressive Namaste" (the images are extracted from a recorded video)

A consistent observation in use of expressive gestures to interact with gestural interfaces opens the debate to accommodate increased range of motion in performing body gestures for low literate users, a guideline also recommended for older adults (Gerling et al., 2012). The debate also expands to performance of body-gestures beyond time constraints and limitations for accurate gesture performance. This may be inappropriate for time critical tasks, but potentially beneficial for similar information systems which are not time bound.

Different variations of gesture performing style were observed across participants. These variations were not limited to gesture styles, but were also observed in standing postures of participants. Participants demonstrated different standing postures while listening to health information. Figure (41, 42) showcases different standing postures observed during the study. While most often standing postures observed were a *normal standing position with both hands towards legs* and *hand fist on stomach* (figure 41), other frequent postures included *one hand on stomach and other hand on chin*, *both hands on waist*, *one hand over another covering the chest*, *both hands on abdomen* and *both hands on stomach* (figure 42). *Both hands on stomach* posture (figure 42.e.) was often observed across participants who were in 3rd trimester. This was mainly due to their increased stomach size during 3rd trimester and ease of keeping the hands over stomach. While these standing postures were natural and presented individual participant characteristics, it influenced the gesture performance. Few postures resulted in false positive, especially when participants moved towards gaining the posture. For example, a false positive of *Previous* function was detected when a participant moved her left hand to hold the arm of her right hand (figure 43.c.). Similarly, transition of a hand movement from stomach to perform any gesture resulted in random gesture detection, most often for Pause function.

Figure 38. Most observed standing postures a) hands still b) fist above the stomach (the images are extracted from a recorded video)

Figure 39. Different standing posture (left-to-right clockwise direction) a) one hand on the stomach and other hand on the chin b) both hands on the waist c) one hand over another while covering the chest d) both hands on the abdomen e) both hands on the stomach (the images are extracted from a recorded video)

Although the postures present individual characteristic of each participant, other parameters (e.g. trimester) also influence them. A careful consideration and inclusion of contextual postures in designing gestural interfaces could avoid potential false positive conditions, especially for interfaces proposing body-centric or body-embodied gestures.

6.4.4 Computer supported co-operative health

A collaborative effort among participants was observed while interacting with the system. The seating arrangement of both study locations allowed participants – spectators and users to be seated together in front of *Chetna*. Spectators (who were also participants) helped fellow participants to perform correct gestures to navigate through the system. During one instance, a participant performed incorrect gesture for *Next* function by swiping just her palm, spectators suggested her to swipe her arm till the stomach. Similarly, when a participant verbally requested the moderator to skip training module, spectators suggested her to point at a skip button. Spectators also suggested viewing unseen information to the participants. For example, one spectator told the participant that, "You did not see folic acid (food habit information) which is the fourth one (pointing at 4th icon on the GUI). You should see that (folic acid)." Participatory approach to system interaction certainly brought confidence among participants, resulting in performing gestures without any hesitation. Statistical data gathering and analysis was not conducted as a part of this experiment, however direction observations suggest a positive impact on confidence building among participants in a public setting.

The findings suggest vital important of spectators in public information systems in developing regions. In this study, a spirit of collaboration and mediation by the spectators was seen to guide participants for better operability and usability. It was observed that complex health information was exchanged among the participants and ASHAs. The system became a starting point for these conversations, instigating computer supported co-operative health awareness learning and helping in overcoming shyness for the subject of pregnancy.

Although, the computer supported co-operative health awareness indicated positive response, it is still restricted to same gender, e.g. female. The results and effect may not be similar in instances where both genders are present during the intervention. The effect of male and female presence during interactions with such a system communicating sensitive health information to rural users offers scope for further investigations.

6.4.5 Technology limitations and challenges

Technology limitation, especially errors in gesture detection were observed due to a variety of causes. One of the causes was in the cultural clothing worn among rural participants. All participants wore traditional saris during the study. Falling of the drape of the sari called *Pallu* was detected by the system as input gesture for *Next* function. In some cases, participants also wore shawl and this was incorrectly detected. Similarly, large movement of long hairs was also taken as input for random gesture detection. Figure 43 showcases two participants wearing sari and shawl respectively.

Figure 40. Participants wearing Sari and Shawl while using the system (the images are extracted from a recorded video)

Accurate gesture detection and technology performance brought confidence among participants. It was observed that inaccurate system performance embarrassed participants whereas correct system performance enhanced their confidence to use the system, especially with participants who used the system for the first time. For instance, one participant was found distracted due to patients movements in the health center. She was found shy and looking around the people at initial stage, however when a system started performing to her gestural commands, she was found completely engaged with *Chetna* and did not bother with spectators' presence. However, when a system did not perform accurately, they were found confused and clueless regarding further actions. Some participants got embarrassed as they thought wrong system performance is due to their mistake. For example, when one user who expected information on food habits found a blank screen (black colored), she got confused and started looking around to search for moderators for further help. Similar situation was found when *Chetna* suddenly stopped working due to technical problems, participant turned around to look for help.

Although, the system did not have major technical faults, but smaller glitches and problems among participants lead to confusion and embarrassment. Owing to low literacy and non-familiarity with such systems, participants attributed the fault to be due to them, when in fact it was a technical fault in the system. This indicates that such systems should be developed to be more rugged. It should also provide immediate and clear feedback to user in case of a non-functionality.

6.4.6 On-field realities and its impact on research

Although section 7.1.1 discusses the reasons behind limited participants visiting the system multiple times, the study also observed other factors those have influenced a number of participants, related findings and results. Throughout the research, this study faced challenges, limitations and had to make compromises to the proposed research goals to the on-field realities. The challenges and limitations were in a form of infrastructural limitations of chosen locations, limited official government support in conducting such a pilot study, high dependency on health workers, interpersonal dynamics among health workers and cultural-geographical and social constraints. These parameters affected the time duration for conducting the pilot study, a number of participants accessing the system and frequency of visits which highly influenced in quantitative analysis and resulted in low statistical confidence. Such disadvantages are often observed and experienced during a field based studies which portray on-field realities and consequently one has limited control over external factors (Mcgrath, 1995; Ramachandran, 2010). This section discusses general tradeoffs of prioritizing methodological rigor over accurately preserving the interaction of contextual realities.

6.4.6.1 Infrastructural challenges

The location for the study was chosen based on a poor maternal health outcome, rural context and users with low technology and education literacy. Considering such extremely challenging conditions, the study attempted to contribute to the neediest PW that could benefit from the proposed intervention. Hence, health centers of Bonmoja and Amingoan were chosen for the study. The tradeoff for this decision was longer distances, unreliable and less transportation services between participants' home and health centers. It also resulted in a poor infrastructural facility of health centers which restricted the time duration for a pilot study. Administrators of those health centers had to vacate their official space for *Chetna* setup, especially in Amingoan which impacted the time duration of the field trials.

The study also experienced limitations due to unreliable electricity on study locations. Often electricity went off while participants interacted with *Chetna*. This resulted in longer waiting time, repeating the study from scratch and listening to the healthcare contents again. This frustrated the participants as they had to wait for extended time till the study restarted. From researchers view point, the data collection was also affected due to system suddenly switching off. The software did not store the data, hence recollected only when the same user performed it again. The study also faced challenges in form of limited infrastructure at the PHC's such as less number of power sockets at local health centers which most of them were not working. This hampered the use of connecting kinect, TV and laptop. Longer extension of electrical units was used to overcome this challenge during the subsequent days.

Distance to health centers were also reported a hurdle due to unavailability of local transport in rural areas. Participants had to walk 3-4 kms to reach the study locations of health centers. This was found to have a negative attitude from family members of the participants. For instance, a mother-in-law (who visited the system along with PW) stated that, "The distance from our home to hospital (health center) is more than 2 kms and it is very difficult for my daughter-in-law to walk that long as she is in 3rd trimester now". Similar concerns of participants were communicated to researchers by health workers. This indicates minimum infrastructure facility benchmark for successful integration of such information system in rural areas.

6.4.6.2 Cultural and social challenges

The study also faced challenges due to a local festival of "Bihu" where participants did not visit the health center for more than 14 continuous days. Although the festival is limited to 5 days, participants perform cultural rituals during remaining days. Participants indicated non-willingness to visit the health centers due to these family rituals involving food preparation and other cultural activities during the festival. Similarly, there is also a belief among the community members which did not allow PW of 3rd trimester to go out of the house 15-20 days prior to due delivery date. This also impacted revisiting of the participants to the health centers. Other social factors such as attending to a family at home, coinciding with the time of system usage influenced participants' motivation to visit study locations. All participants demanded morning visits (post 9.30 a.m. till 11.30 a.m.) as post 11.30 am they prepared lunch for family members, afternoons were utilized for rest and evenings were again spent with family members.

6.4.6.3 Foreign researchers and equipment

Importance of influential factors such as foreign researchers and gap between researchers and the communities of research have been portrayed in various ICTD interventions before (Creswell and Clark, 2007; Burrell and Toyama, 2009). Although the study was carried out with help of local moderators, presence of researchers was needed to overcome technical challenges, ensure smooth functioning and qualitative documentation of participants' interactions with *Chetna*. The researchers were present outside study locations, however participants could see researchers documenting the findings. Researchers wore non-influential cloths (e.g. salwar kamiz) to ensure reduction of external factors.

Participants' were observed to be conscious about their clothing, standing and sitting postures in front of researchers, especially when visiting the system for the first time. For instance, one participant's blouse was slightly torn at right under arm which was in view of researchers. Hence, she performed all gestures with left hand to hide the torn blouse. This resulted in gestures being performed slowly. Similarly, participants' sometimes used their belongings such as carry bags to hide torn parts of their clothing. Participants also greeted the researchers with *Namaste*, tried to remain silent and sincerely participated in the study as spectators. This is observed mainly during their 1st visit to the system. However, over subsequent visits, participants were found relatively casual and started interacting with peer participants more freely.

While the on-field interventions resulted in longer time duration, fewer numbers of participants and unexpected challenges, it emphasizes the importance of real context with peripheral factors and provides a qualitative overview of how it is coupled with final outcomes. Overall, this section discusses the challenges, limitations and unexpected realities faced during the study that influenced its scientific rigor. While the field trials aimed to demonstrate significant gesture learnability over subsequent visits, it could not generate substantial statistical evidence for it. This was due to factors of geographical, social, political and cultural limitations which affected the results significantly. Similar findings of external factors affecting research design and statistical significance have been reported earlier by Ramachandran (2010). This indicates that ICTDs is not solely driven by technology but successful ICTDs also depend on natural counterparts and recognize geographical, social, political and cultural factors present in the chosen context.

6.5 Design guidelines

This section formulates design guidelines to overcome the limitations and challenges in proposing a gestural interface to users of resource scarce regions. Although, the guidelines are formulated through findings identified among low literate users of rural Assam in India, it also has potential to cater to users with varying educational background and among those users who are not familiar with technology. These guidelines are proposed for body-gesture enabled health information systems, however they offer potential to extend themselves to other audio-visual information system in resource scarce regions among similar communities in other developing countries. Following are the proposed design guidelines.

Guideline 1: Posture inclusive design for body-mediated gestures

Design body-mediated gestures that do not infringe upon traditional user postures. The study experienced performance of multiple default postures by participants, which influenced false positive conditions for various body-gestures. Traditional postures may also cause difficulties for body-centric gestures, especially for body centric gesture performed on stomach and chest. Thus, introduce body mediated gestures that are inclusive of traditional postures to interact with audio-visual information system. This can potentially eliminate false positive conditions. The list of possible postures should be tailor made to the local context of use. This can be decided after understanding characteristics of target users instead of adapting universal gesture set across all users. For instance, in this study, the different trimesters influenced the standing postures of PW.

Guideline 2: Gestures with flexible range of motion, speed tolerance and variations in gesture style

Design gestures that are expressive, adapt to users' flexible range of motion, adapt to different gesture styles and tolerate different speeds of performing gestures. Increased gesture learnability in subsequent visit was observed for gestures which were adaptive to variations in gesture styles (e.g. gestures of *Pause* and *Previous* functions) across rural PW. The study also experienced that rural users often perform loud and expressive gestures with high range of motion. Moreover, they were performed at a lower speed in order to confirm and accurately activate the desired selection. To account for this issue, gestures designed for rural users should be expressive, accommodate increased flexibility in range of motion and imbibe tolerance in speed variations while performing body mediated gestures. Limitations in speed and range of motion of gestures, especially for novice users with low technology exposure may lead to errors in execution and recognition. Incorporating full body interfaces according to individual differences in users' range of motion has been reported before for older adults (Gerling et al., 2012).

Guideline 3: Utilization of familiar contextual elements

Mediate interactions through a use of contextual and familiar elements in design of gestural interface among low literate users of resource scarce regions. The contextual and familiar elements include influential person(s) with an already established respect and societal acceptance in similar domain as persona to effectively communicate with users, especially when dealing with socially and culturally sensitive information. Moreover, the system should consider gender relevant issues including socio-cultural taboos and local rituals that influence the design of the interface and its information dissemination. This will help increase familiarity and aide in reducing resistance in accepting the gesture based interactive systems. Similar findings indicating the use of electronic agents of living persons to increase acceptance of information systems for developing regions have been reported before (Grudin, 2000; Agarwal et al., 2010; Basson et al., 2013). Hence, utilization of familiar elements identified based on effective socio-cultural and contextual relationships help users to trust new technology interventions, especially for low literate users with low technology exposure.

Guideline 4: Clear, continuous and consistent instructions

Provide continuous, consistent and clear demonstration of instructions to support gesture learning and its functions, upcoming section of information, navigational options and overall (system) information architecture. Often low literate users have no or little prior experience interacting with technological platforms and are often dependent on other people for assistance, especially platforms using new interaction modalities. To address this problem, clear instructions using local language should be provided to users. Further, use of technical jargons and non-crucial information should be avoided. The instructions should be presented through audio-visual demonstrations for easy adoption and understanding. In case of gestures, an audio-visual demonstration performed by an electronic agent can provide appropriate clues for accurate gesture performance by users. Instructions should also be provided continuously at various stages, especially after completion of information dissemination to remind users of their possible options for further steps of interactions. Moreover, the format of presenting instructions should be kept consistent across the system in order to ensure reduced cognitive effort for users. Clear and consistent instructions are helpful to avoid the need for continuous tutorials or help section of the system.

Guideline 5: Designing with cultural and contextual constraints and limitations

Integrate cultural constraints and limitations to facilitate unhindered system performance and overall user experience. As indicated by Larson et al., (2013) and Sharma et al., (2014) it is important to understand cultural constraints, challenges and limitations from the design phase to development and deployment. Women of rural areas wear traditional clothes (E.g. sari in India) during any occasions outside their homes. Clothing also change based on region and religions in diverse countries like India. For example, women wear banarasi sari and mekhala chadar (traditional form of sari) in the state of Uttar Pradesh and Assam respectively, where pattern of wearing both these saris are different. Clothing and related wearing patterns may possess technology limitations and challenges. For example, pallu of saris often fall down while performing body mediated gestures and sometimes trigger false positives conditions. Hence, to achieve accurate gesture detection and uninterrupted system performance (which potentially influences users' experience), in-depth study of cultural and contextual limitations and their clever inclusion are needed.

Guidelines 6: Gesture interactive tutorials

Introduce the system with tutorials to facilitate interactive gesture learning for novice users. The rural users of developing regions are often novice to new technology explorations such as gestural interfaces. Hence, it is important to train them to impart the skills needed to control and manipulate the system. Tutorials are one such method. Tutorials for users, especially users who use such systems for the first time, should include understanding the system in general and imparting skills on how to use gestures to interact with a system. Moreover, tutorials should not be a mere audio-visual demonstration (Medhi and Toyama, 2007; Medhi et al., 2011; Li et al., 2012), especially for gesture supported interfaces, but should also prompt participants to actively participate through performing gestures for dummy contents. Gesture performance through active participation in tutorials will help users gain confidence prior to using the actual system.

Chapter 7

Summary

This thesis has explored and investigated gestural interfaces for communicating health information effectively among low literate PW of rural Assam in India. The study evaluated the acceptance of gestural interfaces and investigated learnability of body-gestures as input interaction modality across the targeted user group of rural PW.

The thesis started with an aim to understand the context of maternal healthcare in India and further in Assam, which was a facing challenge of highest MMR in India and demanded immediate interventions. The literature study portrayed ICTs – especially mobile phone supported interventions as a potential alternative to overcome the challenge of poor maternal health conditions, however faced limitations of poor usability, smaller screen sizes, low technology literacy and non-relevant modes of interaction. To overcome the challenges and limitations, it began understanding possible alternatives using natural interaction modalities for communicating with ICTs, especially learning and analyzing the literature on gestural interfaces in HCI. The literature revealed a research gap demanding an investigation on the effectiveness of body-gestures as interaction modality in resource scarce regions, especially across low literate users with low technology exposure. Overall, the literature study helped to build the broader theme of this research to (a) overcome the challenge of poor maternal health conditions in Assam and (b) investigate gestural interfaces among users of resource scarce regions. This further developed in our hypothesis that aimed to investigate acceptance of gestural interfaces among rural PW of Assam in India. Moreover, gestures being a natural and day-to-day communication medium, it also aimed to examine the learnability of body-gestures as input modality for ICTD systems across rural PW.

4 major study experiments – contextual inquiry of people associated with maternal healthcare, focus group studies with doctors, focus group study with ASHAs and PW and user generated gesture study were conducted to identify contextually suitable design elements. Study experiments of contextual inquiry and focus group study with ASHAs and PW revealed important design elements such as - need of educating PW about maternal healthcare, ASHAs as influential actors having a potential to motivate rural PW, female gender prevalence in maternal health discussions, TV as a relevant technology platform with relatively high familiarity than other technological mediums, instructional methods of information dissemination and demonstrated socially relevant ways for sensitive health information communication. The findings of contextual inquiry revealed an immediate need to educate rural PW about practices of healthy motherhood, which lead to a focus group study with health experts revealing 3 categories of health information necessary to educate rural PW – S&R, T&C and FH. This was followed by a 4th study experiment, which aimed to identify suitable body-gestures to operate interactive health information system. The experiment first conceptualized 7 computational functions - *Select, Pause, Resume, Next, Previous, Activate Menu* and *Help* which were further presented to PW along with a task in order to identify user preferred gestures. The collection of user preferred gestures was further filtered based on a frequency of gesture performed for each computational function, logical mapping of gestures to function, semantic representation of gestures and to reduce false positives. The filtering was done to elucidate final gestures to operate 7 computational functions. This helped identify 7 body-gestures – *Pointing, Halt with & without arm stretched, come back I, horizontal arm swipe (right-to-left) and vice versa, bringing two arms together* and *raising any arm above head for 2 seconds.*

Overall, 4 study experiments aided the thesis in collecting user supported suitable elements to design an interactive health information system to educate PW.

The findings identified from 4 study experiments resulted in a TV based gesture enabled health information system called *Chetna*. *Chetna* used audio-visual medium to showcase maternal health information in local Assamese language. The health information and navigational instructional were demonstrated through a virtual agent of a health worker. The virtual avatar of PW enacted the health symptoms which were verbally commented by virtual agent of a health worker. The system used a familiar background of traditional Assamese bamboo structured home and a local health center look-alike environment to present information experienced at home and health center respectively. The system navigation was divided mainly in 3 stages – (i) user authentication and login (ii) gesture interactive training module (ii) health information dissemination. Body-gestures were detected using Microsoft Kinect^{TM} whereas audio-visual demonstrations of health information were created using Maya^{TM} software.

Chetna was further deployed at 2 health centers in rural areas of Assam for 2 months each. The field trails aimed to investigate the acceptance of *Chetna* and examined the learnability of body-gestures as interaction medium. TAM3 with its determinants of PU, PEOU, OUT, BI and an independent construct of EPS was employed to investigate acceptance of *Chetna*. Participants' response was recorded using 5 point semantic differential scale. Total number of gestures performed, type of gesture performed and errors in gesture performance were collected through a database to investigate gesture learnability over subsequent visits to the system. The field trials used a non-traditional method of participant recruitment, where the system was made available for all PW to visit at health centers. The local ASHAs acted as moderators and they were encouraged to bring their PW to use the system. ASHAs were briefed about the system aims, objectives and interaction methods.

Total 63 participants visited the system over a period of 4 months, out of which 13 had visited the system 3 times. Total 612 information with 339 S&R, 212 T&C and 66 FH were viewed by the participants. Total 2417 gestures were performed with 131 and 52 of technical and participants' errors respectively. Overall, the results revealed participants increased inclination towards system acceptance with usability constructs being consistent for all 3 visits. The results also suggested significant increase in BI representing participants' willingness to revisit the system, especially after 2nd visit. These results were consistent across all age group of PW who participated in the study. No significant difference was observed for overall gesture learnability among participants, however the results revealed a significant learning of body-gestures for the functions - *Pause, Previous* and *Help.* Gestures of functions – *Select* and *Resume* were error free whereas gestures of functions – *Activate Menu, Next* and *Help* were indicative of increased learning. The field trials also revealed qualitative findings such as influence of socially and contextually relevant design elements such as a virtual agent of ASHA and use of female character in acceptance of new technology platforms; impact of placement of GUI icons and instructional approach for easy and effective system navigation; gesture errors due to variations of speed, time, range of motion and participatory approach in gesture performance; standing and sitting postures of participants and influence of cultural clothing in accurate gesture recognition. The results also presented an impact of infrastructural limitations and socio-cultural challenges, which resulted in shorter duration of field trails, system usage and reduced participants' revisit; emphasizing the importance of real context for research demanding scientific rigor. The findings were further analyzed to present 6 design guidelines – (i) posture inclusive design for body-mediated gestures (ii) gestures with a flexible range of motion and tolerance in speed (iii) gesture interactive tutorials (iv) utilization of familiar persona (v) clear, continuous and consistent instructions (vi) designing with cultural and contextual limitations for designing gestural interfaces among low literate users of resource scarce regions.

Chapter 8

Conclusion

This thesis explored the space of body-gesture enabled ICT interventions to overcome the challenges of poor maternal health conditions in rural Assam in India. It investigated acceptance of gesture based health information system of *Chetna* and examined learnability of body-gestures across low literate PW. It began with a series of user centered study experiments which established the need to educate rural PW, emphasized the importance of ASHAs and female community members in improving a maternal health ecosystem and identified TV as a suitable platform to increase technology acceptance. It further elucidated a series of 7 user preferred gestures to control computational functions. These findings were further incorporated into the design of *Chetna* – TV based gesture enabled health information system to educate rural PW. Field trials for a period of 4 months at 2 different locations in rural Assam were conducted to investigate the hypothesis. The results were indicative of acceptance of *Chetna* with consistent usability and increased willingness to revisit the health information system. All body-gestures did not find significant learnability, however body-gestures of functions of *Pause*, *Previous* and *Help* found statistical confidence of increased learnability for subsequent system visits. The thesis also emphasized on the importance of socially influential actors, variations in gesture performance, socio-cultural elements on accurate gesture recognition and infrastructural limitations and socio-cultural challenges in persuading healthy motherhood in resource scarce regions. Finally, it presented 6 design guidelines in order to design gestural interfaces for health information communication in among low literature users of developing regions. Although these guidelines were identified from the findings of field trials conducted among low literate rural PW, it offers potential to be utilized in designing gesture based ICTs among low literate users of resource scarce regions.

Overall, this research work laid out 5 major contributions which were reported at the beginning of this thesis. Following are the contributions reiterated.

1. Detailed user research of maternal health in rural Assam in India. Problems related to maternal healthcare, findings and analysis of socio-cultural issues and technology usage and understanding of PW
2. Collection, extraction and elucidation of gestures generated through a user generated gesture approach for operating identified computational functions
3. Evidence that gestural user interfaces are well accepted among rural PW of developing regions
4. Evidence of increase in learnability of individual body-gestures over subsequent system interactions among rural PW of developing regions
5. A series of guidelines for designing gestural interfaces for users that could potentially improve the chances of its acceptance in resource scarce developing regions

8.1 A reflective note from the researcher

This research work dwelled into a domain of gestural interfaces for resource constrained regions, which was not sufficiently explored yet. Despite context based field trials for 4 months among targeted users, it still offers a large room for exploration and future research work in this space. The research experiment and analysis was confined to 2 health centers in rural Assam. The statistical confidence was also limited to 13 participants due to social-cultural-political limitations and time-duration constraints. Although, the study indicated system acceptance and partial learnability of individual gestures, it still remains to gain strong statistical evidence with a larger number of participants. The most important reflective viewpoint of this research is a need to further extend it to a large scale pilot study to

(a) gain strong statistical evidence and confidence on the findings presented and (b) create a larger impact benefiting needy users. The large scale pilot study investigating these factors should not sacrifice the contextual realities for implementation of successful ICTs. The large scale pilot study is currently in discussion with government authorities.

Successful ICTD interventions are not alone, but depend on natural counterparts surrounding the domain ecosystem (Warschauer, 2004). A strong point of this research was an attempt to be as realistic as possible, present on-the-ground findings and preserve as much context as possible. Although the findings are not entirely unique to this study, it still offers potential parameters for successful deployment and impact of body-gesture enabled ICTs in key development areas. A bigger aim of any research study is to create larger impact, especially in the contexts of ICTs which offer tremendous opportunities to solve major societal challenges in resource constrained regions. This study attempted to balance scientific rigor amidst unexpected field realities and did not isolate socio-cultural, geographical and political factors that exists in the context.

This research work reflects the importance of socio-cultural elements – from design of GUI, information communication methods and usage patterns of the proposed system of *Chetna*. It considered important socio-cultural issues of a north-eastern state of Assam in India, which is often different from other states in India and different from other countries across the world. It would be worth investigating user behaviors and usage patterns if similar gestural interfaces are deployed across cultures, especially for communicating culturally sensitive information. For instance, a body-gesture accepted in rural Assam may not be suitable for participants with different cultures. Moreover, issues of gender prevalence, social hierarchy and type of targeted user group will play a larger role in acceptance of gestural interfaces. Taking a step further, gesture interfaces deployed at multi-cultural contexts (e.g. airports, railways stations etc.) would reveal new directions of research and guidelines demonstrating the impact of socio-cultural factors in using such interfaces.

8.2 Scope of future research

The qualitative findings identified through direct observations and analysis of video recordings during the study established new directions of research in the domain of gesture supported interactive systems. Although these findings did not present statistical relevance, it reported substantial impact on system acceptance, usability, usefulness, gesture learnability and final results of the proposed gestural interface. Following section elaborates on the key findings which new proposals for further research in investigating overall effectiveness in gestural systems among low literature users of resource scarce regions.

8.2.1 Investigating memorability of body-gestures

The study reported various socio-cultural factors which resulted in inconsistent time gap between subsequent visits and system interactions. While the gesture memorability has been a topic of discussion in gesture based HCI, it has not been investigated with inconsistent time gaps in subsequent system interactions among low literate users. This opens a scope for future research in investigating gesture memorability and recall, especially where contextual realities influence the time duration between subsequent interactions with gestural systems. The scope of this research investigation is not restricted to rural PW, but can be expanded for any such systems that require continuous interactions with proposed systems in developing regions.

8.2.2 Investigating effectiveness of participatory approach to system adaptability

The study observed a combined effort among spectators and participants to view the presented health information and accurately navigate across the proposed gestural interface. *A spirit of collaboration and mediation by the spectators was seen to guide participants for better operability and usability*. This presents a proposal to further investigate influence of participatory environment in system adaptability, usability and acceptance. The dynamics of spectators and participants for collaborative learning can be verified and further compared with systems proposing individual interactions. The proposal can take step further by investigating dynamics of different genders for collaborative learning in system acceptance, especially for systems supporting gender sensitive issues (E.g. sexual wellness, HIV etc.)

8.2.3 Investigating contextually relevant design elements in effective adoption of sensitive information

The study reported positive behavior of participants towards contextual design elements, e.g. virtual agent of ASHA and PW, home and health center environment for imparting culturally sensitive maternal healthcare information. Although the effectiveness of familiar characters as personas has been reported before, an investigation of using contextually relevant elements for designing a system GUI for imparting sensitive information is still in nascent stage. What if symptoms related to lower abdomen are presented through its pictorial presentation and verbal commentary by virtual agent of ASHA? Will it demonstrate equal acceptance for a system that uses instructional method of verbal communication along with visual demonstration by a virtual agent of PW in a traditional home environment?

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Appendix

Appendix A: Contextual Inquiry questionnaire

The study followed a method of contextual inquiry through semi-structured interview process. Hence, the queries are semi-structured and kept open-ended in order to modify them to suit the flow of the interview. The experiment ensured to cover major aims and objectives of the research.

Aims and Objectives:

Needs and problems:

What is the current state of maternal health care? What are the problems faced by PW during pregnancy? How does a PW or family members currently manage tests, checkups and overall pregnancy related issues?

Information gaps:

What is the current state of information awareness of government health schemes and healthy pregnancy? What is the current source of information?

Socio-cultural issues:

What are the current social and cultural norms followed during pregnancy and post pregnancy among the targeted community? How do family dynamics influence decision making during pregnancy?

Technology usage:

What is the current technological usage among users? What are the current levels of technology literacy among targeted user groups?

Overview of specific questions

- Brief introduction about the purpose of our research.

- Can you briefly describe yourself, especially family members, occupation, approximate family income and your current stage of pregnancy
- Had you conceived before or is this your first pregnancy?
- When is your due delivery date?
- Are you availing government supported services? If yes, then how did you know about it?
- What is the procedure followed to join the NRHM supported initiatives?
- How did ASHA help you in the complete process?
- Did she explain you any information for healthy pregnancy?
- Do you go alone to health centers or you are accompanied by your family members?
- How does your family member support you during your pregnancy? E.g. help in medication, household work, hospital visits etc. Explain through role of each family members
- What do you think the problems you have faced till now during your pregnancy?
- Have you come across an emergency situation during your current or past pregnancy?
- Are you aware of all the government services provided to the pregnant women? How?
- Do you ever read the health information brochures in health centers or anywhere in your village? Or any information obtained from medical card?
- Are there any specific rituals associated in different stages of pregnancy? Can you explain them in detail?
- What kind of technological objects do you use? E.g. TV, radio, mobile phone etc.
- How many mobile phones do you have and how often do you use it?
- What kind of features do you use in your mobile phone?
- Have you ever tried any advance features such as setting a reminder, alarm clock, accessing internet etc.

- Do you try to learn advance features on the mobile phone from anyone in the community?
- Can you explain the role of your village or community in pregnancy?

Appendix B: Contextual Inquiry

B.1 Introduction

India, a country of multiple states, languages and dialects, literacy levels, socio-cultural-political norms and beliefs and technology exposure demands multi-dimensional investigative studies to understand the contexts and users. Hence, a contextual inquiry through a semi-structured interview approach was conducted. This was done to understand maternal health conditions, users' needs, problems and behaviors to identify contextual design elements suitable for interventions across targeted users groups.

B.2 Aims and objectives

The preliminary objectives of this study were need assessment, problem identification, behaviors, technology literacy and usage and socio-cultural dynamics. Each objective is discussed below.

Needs and problems:

What is the current state of maternal health care? What are the problems faced by PW during pregnancy? How does a PW or family members currently manage tests, checkups and overall pregnancy related issues?

Information gaps:

What is the current state of information awareness of government health schemes and healthy pregnancy? What is the current source of information?

Socio-cultural issues:

What are the current social and cultural norms followed during pregnancy and post pregnancy among the targeted community? How do family dynamics influence decision making during pregnancy?

Technology usage:

What is the current technological usage among users? What are the current levels of technology literacy among targeted user groups?

B.3 Procedure for conducting contextual inquiry

Contextual inquiry through a semi-structured one-to-one interview approach was conducted with 61 people comprising the mix group of PW, health workers and family members to identify needs and problems, socio-cultural issues related to maternal health and technology understanding among the targeted user group. Over a course of 6 months, a field study was conducted across 4 villages - Belkona, Katinpahar, Amingaon and North Guwahati in Kamrup district and 4 tea gardens in Dibrugardh district of Assam, India. The locations for the study were chosen after consultation with NRHM authorities where higher maternal deaths were identified in past few years. Figure 4 outlines locations of the study.

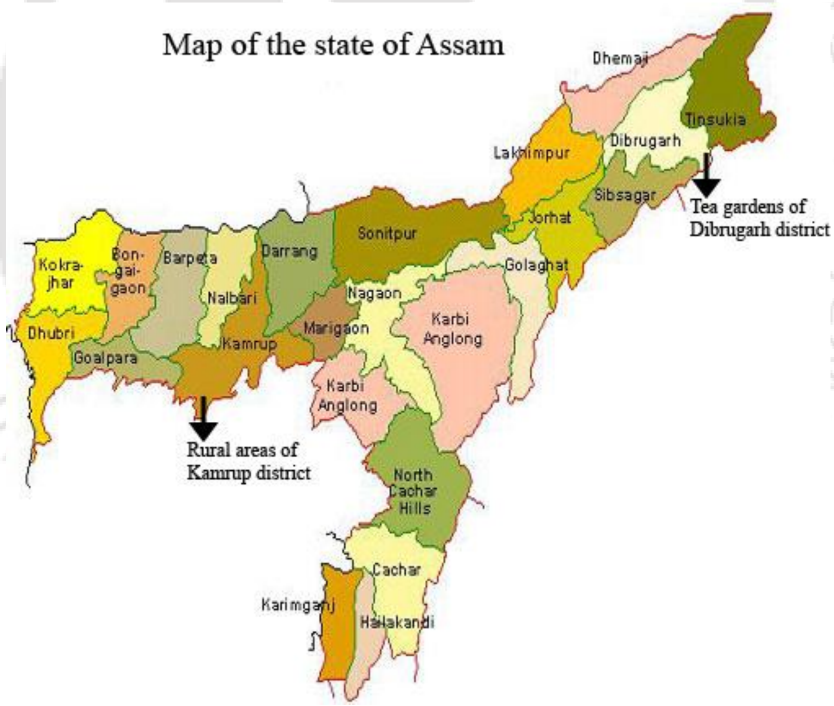

Figure 41. Identified study locations – Kamrup district and Dibrugarh tea gardens

B.4 Participants for the contextual inquiry

Total 61 people associated with maternal healthcare were interviewed. The interviews were conducted through a semi-structured approach through one-to-one interaction with users. Out of 61 people, 38 were PW, 10 were husbands, 11 were health workers and 2 were doctors of local health centers. PW were recruited through references of ASHAs and doctors, as ready-made database of PW of their community was available. All PW were enrolled under NRHM schemes and were assigned one ASHA to look after their checkup and visits to health centers. PW and their husbands' were interviewed at their respective homes whereas health workers and doctors were interviewed at health centers. Users from rural Assam were from lower middle-class families with an average earning of 4000 to 7000 ($90 to $140) per month whereas families residing in a tea garden earned INR 1400 to 1800 ($25 to $40) with most users being semi-literate or illiterate. Most users of tea gardens had migrated from different places in search of work. 2 PHCs, 2 SCs, 1 CHC and 1 anganwadi were visited during the study.

The interviews consisted of 2 researchers and a moderator chosen from a local community to translate Assamese into Hindi. The questionnaire broadly consisted of basic introduction of the user to increase familiarity and build confidence with researchers, their pregnancy goals, the problems faced during pregnancy, family support (especially from mother-in-law and husbands), local rituals followed during pregnancy, existing modes of knowledge gathering and technology usage and understanding. Interviews were conducted for an average 30-45 minutes and recorded using an audio recorder, written notes and photographs. Permission was taken from each user before recording the interview. Only 2 interviews were conducted in Hindi, whereas all other interviews were conducted in local language, Assamese.

B. 5 Insights and findings of the contextual inquiry

Data gathered from contextual inquiry across 4 villages - Belkona, Katinpahar, Amingaon and North Guwahati and Dibrugarh tea gardens resulted in following insights.

B.5.1 Need for imparting appropriate maternal health information

Multiple healthcare schemes were offered by the government health department under the central government initiated NRHM. The schemes offered free medical tests such as ultrasound test, urine test, blood test etc., and other medical benefits such as iron tablets, TT injection and monetary benefits. While each PW was found enrolled under NRHM, most of them were found unaware of the healthcare schemes and services offered by NRHM. PW were found unaware of such medical benefits and significance of such services in healthy motherhood. For instance, very few PW knew about the significance of ultrasound tests in rural areas. Similar cases were identified among the users who were pregnant for a second or third time. One PW, who was pregnant for the 3rd time mentioned that, “I do not know what tests and checkups I go through, but whatever ASHA tells me I follow it”. Such lack of awareness and knowledge had led to many problems among users in rural areas. It was observed that one such problem was doctors reporting the tests in the medical card without actually performing any such tests on the PW. For instance, one PW from a local tea garden stated that she was never given tetanus injection, however medical card indicated otherwise. Following are few excerpts from conversation with her.

- Moderator: (looking through the medical card) So, you have been given TT injection during your 2nd ANC (last visit to the health center)
- PW: what is TT injection?
- Moderator: You must have been given an injection to avoid tetanus infection.

- PW: No, during my last visit, I was not given any injection. I went, met the doctor, he signed this (medical) card and returned back to me

The lack of information awareness was not limited to the government supported services, but was also observed across other pregnancy dos and don’ts. One consistent observation was inappropriate food habits. PW from tea gardens consumed high amount of salted tea that caused anemia, however no PW was found aware about causes of consuming salted tea. Similarly, locally available food such as banana flower is high in iron content, however its consumption was found low due to unawareness of its nutritional value. When educated on health benefits of banana flower, one PW responded by saying, “Oh, I did not know about this (health benefits) of banana flower. Nobody in the village also told me about it”.

Existing health information awareness resources were either not available or not accessible. Medical cards were one such source of health information. This was considered more of a liability in seeking government health services instead of being an information resource. They were mainly used to complete administrative formalities e.g. filling relevant information and signing the medical card. Figure 1(a) demonstrates a doctor completing formalities on the medical card for PW after their checkup.

Figure 42. Doctor signing the medical card of a PW in order to complete administrative formalities

Information brochures placed at health centers gave basic maternal health information in the local language, but there were found ineffective due to following problems

a) Information brochures were placed at unreachable places, e.g. the backside of health centers, placed at unreachable height etc., hence no PW were motivated to read the information.

b) In rural areas, most users were illiterate or semi-literate, so they could not read the information. The information was also found to be outdated sometimes.

Figure [6(a) & (b)] shows the information brochures placed at non-relevant places in two major health centers

Figure 43. (a) information stand on an opposite side of the entrance at a health center (b) wall mounted information brochure on backside of a PHC

B.5.2 High dependence on ASHAs

A high dependence on ASHAs was observed during the field study. ASHAs are involved from the starting of pregnancy. Their responsibilities included registration of PW, tests and checkups, reminding for hospital visits for ANCs, assisting PW in availing government services, institutional delivery and post-pregnancy benefits. All PW trusted ASHAs and discussed pregnancy related problems with them. Below is the transcription of one of many such conversations with PW to understand the influence of ASHAs during their motherhood.

Researcher: Have you gone through any ANCs till now?

PW: yes, I have gone through 2 ANCs till now. I have gone to nearby health center for checkup.

Researcher: How did you come to know about the ANC? Who took you there?

PW: ASHA didi (sister ASHA) had come to our house asking about my menstruation cycle few months back. She took me to hospital for checkup where she registered me and gave me a card (medical card). During my first ANC, she came to my house one day before to be ready next day for hospital checkup. This was done during 2nd ANC too….. She also gave her mobile number to me and told that I can call her if there is any emergency"

Researcher: Have you ever called ASHA for an emergency?

PW: No, till now I have not called ASHA but my neighbor had called her during labor pain. She (ASHA) helped to take her to the hospital, do (administrative) formalities….. I know she will help me too.

In another instance, when asked about emergency situations, one PW stated that, "In-case if I get any complications, I will call my ASHA and she will take me to hospital". Similar statements such as "ASHA helps me to go to the hospital, avail all benefits and take care of my pregnancy", "Whenever ASHA calls us, we go and follow whatever she says" etc. were stated by PW. Additionally, recruitment of ASHAs is designed to ensure their acceptance among the community. With a minimum qualification of eighth grade, they are often recruited from respected community members by a village council. They are responsible to periodically visit every house, identify PW and ensure their enrollment for government health services. This helped PW and local communities build a cordial and trustworthy relationship with ASHAs. From these observations, it can be noted that generating trust through a community insider becomes important for the successful implementation of any intervention between semi-literate members of a village community, especially for health issues among women.

B.5.3 Gender issues in a social system

Issue of gender becomes important to consider when one discusses pregnancy related topics in rural areas. PW were found shy discussing their problems with male members of the community including husbands, male family members and male doctors. No discussion was seen between PW and male doctors. Doctors mainly signed the medical card and completed other administrative formalities ensuring support to avail government health services. While husbands do support to impart confidence among PW, they did not directly discuss pregnancy complications and symptoms. While interviewing one PW in order to understand influence of her husband on her pregnancy, she stated that, “My husband is very supportive. He takes me to hospital, sometimes helps me in household works and takes care of me. But I do not discuss pregnancy complications with him, as such things (pregnancy issues) are not male related things. I discuss all my problems with Latika (local ASHA)”. Similarly, one other PW stated that, “Pregnancy is not a male thing, and if I tell him (husband), he will not understand”.

B.5.4 Familiarity and acceptance of TV interface

Even though contextual inquiry aimed to understand needs and problems faced by PW, a major motivation of the research was also to understand technology literacy aspects and their impact in design of gesture based system.

Despite high penetration of mobile phones in India, usage of mobile phones was found very low among rural PW. They were mainly used by a male member of the family e.g. husbands. PW used mobile phones to call and communicate to her family members that were mainly operated by husbands. Upon inquiring a PW whether she has a mobile phone, she stated that, “I have a mobile phone but it is with my husband. He takes the phone to his workplace, as he needs to call vendors for required items…. I use phone to call my mother and sister. My husband dials the number and gives it to me to talk to my mother”. It was observed that PW who had mobile phones used it mainly for calling their parents and relatives. No PW had used other features such as messaging, an alarm clock or tried saving any contact information. Only five PW had their own mobile phone and carried it with them. Only one PW was found mentioning usage of additional features on a mobile phone. She said that she listens to songs on her phone. A section of her interview is described below, Moderator: Do you use features like messages, alarm clock or listen to songs on your (mobile) phone?

PW: I do not message anyone as I use that balance to call my family. I listen to Assamese songs from my phone.

……..

Moderator: How did you store them?

PW: I did not store them, I asked the (mobile) shop owner to feed Assamese songs into my phone. I try to listen to few songs while doing my household activities.

Field studies undertaken with participants from the tea gardens showed that most PW or their family members from tea gardens did not have mobile phones. These users are mostly migrant labors from neighboring regions who have crossed over to Assam in search of work. Financial constraints associated with purchasing a mobile phone as well as calling expenses were found major reasons for not owning a mobile phone.

However, use of TV was prevalent in rural areas for entertainment purpose. Direct to Home (DTH) connection based TV was used to watch family serials on different channels. Most PW were housewives and passed their free time watching entertainment channels on TV. They were familiar using basic TV remote control interactions especially with changing of channels and to increase or decrease the volume. TV was found at few homes in tea gardens where the workers and their family members use to gather to watch regional and national movies. Figure 7 shows a DTH setup situated above a house in rural Assam.

Figure 44. A rural house with DTH connection in Belkona

B.6. Concluding comments on the contextual inquiry

This section presented qualitative findings of a contextual inquiry conducted across 61 people in rural areas and tea gardens of Assam. The inferences identified from the findings strongly suggests lacks of basic pregnancy knowledge among PW, high influence of local health workers-ASHA in persuasion and motivation for availing health services, high regards and cordial bonding between PW and ASHA, high prevalence of gender issues and familiarity with TV interfaces.

Overall, the study establishes a clear need to empower PW with pregnancy related information. This information should not be limited to a mere demonstration of government health schemes, but also portray how it is done and its significance, motivating them to avail services with care. Information demonstrating dos and don’ts of pregnancy and information specific to the context, such as existing food habits can add new benefits towards the goal of healthy motherhood. A cordial relationship and high regards to ASHAs can also be leveraged to effectively impart relevant health information. This is supported by gender bias towards females to discuss pregnancy issues which suggests interactive system with female characters for higher acceptance. Usage of socially influential actors, often called personas has earlier been portrayed effective for information dissemination (Agarwal et al., 2010).

The study also suggests low usage and low literacy of a mobile phone, which demands interventions on familiar platforms such as TV for quick technology adoption and acceptance.

This section provides the detail of questionnaire used during the contextual inquiry. Further, a series of tasks and relevant details used during gesture study are also elaborated here.

Appendix C: Gesture Study

This experiment aimed to investigate suitable body-gestures to operate with conceptualized health information system. It used "user generated gesture study" approach to design the most natural gestures for targeted user group. Following details provide the tasks given to PW and related details during the study. The study was moderated by ASHAs (local health workers). The study was conducted in a local Assamese language.

- Introduction to the study to all participants

  All participants and gathered at one location and further instructed to pay attention to the details of the study
- Task introduction by ASHAs (to individual participant)
  - Introduce the objectives of the study – identify most natural gesture for specific computational functions.
  - A seat is kept, incase if you get tired, you can sit on it and perform the task. Please feel free to stand/sit and perform task
  - We will give you one function, of which you will have to describe it with a gesture.
  - Whichever comes naturally to you, you can perform those gesture
  - Do not feel hesitant and you are allowed to perform what you feel is right

- Task explanation

Imagine there is a system on which your favorite Assamese video song is playing. The system is distant from your position. You want to modify few things, out of which the first is,

(All these functions can only be performed through gestures)

(Participants are allowed to use perform any number of gestures)

(Participants are not allowed to discuss the study with other participants. They will be provided food in another room)

- **Select**

  Imagine there are list of your favorite songs in front of you. You want a “select” a song from this list. How would you do it?

- **Pause**

  Assume that your neighbor has called you for some urgent work and you want to pause that song. How would you do it?

- **Resume**

  Your work with neighbor is complete and you are back at home. Now you want to play the song. How would you do that?

- **Skip (Next)**

  You are bored of that song and you want to skip this song and play the next song. How would you do that?

- **Main Menu**

  You have listened to many songs now. You want to go back to main menu where all songs are listed. How would you do that?

- **Help**

  You want to save the ongoing song. But you do not know how to do it and you require help to save the song. How would you call for help?

Appendix D: TAM3 Questionnaire for System Acceptance Evaluation

Appendix D present the details of evaluating parameters used for gesture-based GUI experiment. The parameters are adapted from TAM3 questionnaire

- PEOU 1 – My interaction with the system is clear and understandable
- PEOU 2 – Interaction with the system does not require my mental effort
- OUT 1 – The quality of the output I get from the system is high
- PU 4 – System is useful to help me learn important maternal health information
- BI 3 – I would like to revisit this system
- EPS – I did not experience physical stress while performing the gestures

Appendix D: Description of focus group videos in English language

Overall, the transcript videos showcase Accredited Social Health Activists (ASHAs) explaining other pregnant women (PW) about better health practices during different stages of pregnancy. The ASHAs divide the explanation into two major stages – (i) explaining the purpose of the focus group and (ii) points on healthy practices during different stages of pregnancy. Following section provides a brief and important points discussed during the focus group.

Stage 1 (verbally explained by ASHAs): The project has come from IIT Guwahati and health department to help local PW. Here, I will explain few tips for help you for better health during pregnancy. Listen to them carefully as that will help you for healthy pregnancy.

Stage II:

- During pregnancy what should be our food habits, weight measurements and what should be done - Every week you should aim to gain half kilo weight nor less nor more. If weight is more or less than what it is said, the baby would not be a healthy baby, so please ensure to check your weight regularly during pregnancy.
- You will often fell backache during that period, so try to sit straight as much you can. If you sit straight, then you will feel less backache. After all, you have to think for yourself as well as for the baby.
- Take rest when your lower stomach (abdomen) pains. Please consider one more thing while resting - sleep by your left side because it's good for the mother as well as for the baby. One more reason that your lower stomach pains is due to the gradual size increase of the baby.
- Sometimes there is itching problem because the upper skin of your stomach becomes thinner, at that time we consult a doctor for some ointment to get

relief from the itching problem. This is a common problem observed during pregnancy

- Appropriate diet during pregnancy is very important. You should have a healthy diet that should consist of egg, fish, meat etc. so that the mother as well as the baby stays healthy. Food should not be taken in large quantity, but should be taken in small quantity and frequently.
- During that period the digestive system works less, hence soft vegetables should be consumed. At that time try to eat minimum salt to eliminate the swelling of body parts. Sometimes, when mother is not able to eat her regular food, ensure that she eats some other things such as fruits or whatever she likes or is allowed o eat.
- It is also seen that many mothers complain about chest burning before delivery or after delivery. In such cases, plenty of water (minimum 3 to 4 liters of water) must be consumed. If mothers cannot drink water, ORS or coconut water must be consumed.
- During 5th month of the mother tetanus injection is given so that the baby and the mother stays healthy. In early times there was not such medical facilities as today. Hence, the mother must get regular checkup for a healthy baby and if there are any complications then the medical team can tackle the problem before time.

The focus group study was observed live and post study through video observation to identify accepted communication method for disseminating sensitive maternal health information.

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