Exploring integration of traditional and digital textiles and experimenting its role for non-verbal communication in the social space of users

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of

Doctor of Philosophy

By

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DECLARATION

I hereby declare that the work contained in this thesis entitled "Exploring integration of traditional and digital textiles and experimenting its role for nonverbal communication in the social space of users" has been done by me, a PhD scholar, under the supervision of Professor Pradeep G. Yammiyavar, at the Department of Design, Indian Institute of Technology Guwahati (IITG), Assam, for the award of the degree of Doctor of Philosophy in Design. Research findings of other researchers has been duly cited and acknowledged. The research work done and reported in this thesis has not been submitted for the award of any other degree or diploma at IIT, Guwahati or any other educational institute.

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CERTIFICATE

This is to certify that the work contained in this thesis entitled "Exploring integration of traditional and digital textiles and experimenting its role for nonverbal communication in the social space of users" submitted by Ms. Deepshikha to the Indian Institute of Technology, Guwahati, Assam (India) for the award of the degree of Doctor of Philosophy has been carried out under my supervision. This work has not been submitted elsewhere for the award of any other degree or diploma.

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Dedicated to my mother

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Abstract

India has rich and extensive textile traditions across the country largely owing to its historical, geographical and cultural uniqueness. In recent times, textiles have been found to be an interesting medium for embedding electronics to impart augmented functionalities, beyond clothing or furnishing. With a gradual decline in craft practices of India over the decades, the plethora of crafting traditions provides immense opportunity to embed and explore possibilities of digitisation and to assess the impact it is likely to have on the Indian users. The problem that the present research addresses is that there is a gap that exists between the hierarchical textile crafts of India and technological advancements pertaining to smart materials at present. There is lack of research and exploration pertaining to e-textiles, scientific research on behavioural aspects of traditional clothing in India in comparison to extensive studies being conducted elsewhere. Combining wearable technology with traditional crafts, designers can create contemporary products for context specific applications to bridge the gap between crafts, fashion, technology and user acceptance. The focus of the research is to embed electronics seamlessly by replacing traditional elements with smart materials to enhance the functions of a static traditional textile. The work focusses on identifying how could craft based e-textile interfaces be designed and how could these interfaces be evaluated, which then generates a heuristic framework for other designers and researchers in similar domain. The user centric design research was conducted in three specific stages - (i) Understanding the users' perception towards traditional textiles and socialisation behavior; (ii) Design Exploration; and (iii) Experimentation and Validation. The research connects three primary domains of traditional textiles, smart technology and the users that use these smart products in their respective spaces of interaction, the social space. Quantitative and qualitative analysis of the findings of studies conducted reveal that traditional textiles of India strongly influence emotions, personality, attitude, opinion, preferences and self-expression of young Indian users. Users believe that textiles are a natural extension of their personality and it enhances their expressive capabilities. The findings also reveal that significant levels of emotions, feelings, boundaries and comfort levels are experienced by users in their social space. Thus, it was hypothesised that digitized textiles with augmented function could enhance non-verbal expression in the social space of users, which could be communicated subtly in specific scenarios and only when needed. Experimentation was conducted for non-verbal expression of emotions and feelings which validate that the digital textile wearable crafts

have been found to significantly express emotions and feelings in the social space of the users. This ensures smooth interaction among users while maintaining a decorum in the social space enhancing the overall collective intelligence. It was also found that users have high preference for using digital craft textile wearables based on perceived usefulness and perceived ease of use. To summarise, the present research finds its inspirations in the elaborate textile crafting traditions of India and an inquisitiveness to merge it with smart materials for context specific applications which could bring them at par with technologically advanced e-textiles of present and benefit designers, researchers and crafts persons.

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Abbreviations used in this thesis

1. LED – Light emitting Diode
2. SI – Social Intelligence or NVC – Non-verbal Communication
3. SUS – System Usability Scale
4. TAM – Technology Acceptance Model
5. IBM SPSS - International Business Machines Statistical Package for Social Sciences
6. PCA – Principal Component Analysis
7. Prototype 1 – *Aster* – LED Embedded hand crafted scarf 1
8. Prototype 2 – *Iris* - LED Embedded hand crafted scarf 2
9. Prototype 3 – *Nymphaea* - LED Embedded hand crafted scarf 3
10. Prototype 4 – LED Embedded jacket
11. IITG – IIT Guwahati, Assam, India

Working Definitions

1. Usability – Measuring quality of users' experience
2. Traditional Textile – Refers to the handcrafted and handwoven artefacts being produced at the craft clusters of India, unless being referred to another culture for a comparative study
3. Cultural Communicators – Traditional artefacts have been embedded with cultural meanings in the form of motifs and colors which carry beliefs of the users thus communicating the essence of particular culture
4. Smart Technology – The use of embedded electronics (digitization) to make textiles perform a denoted function to augment user interaction
5. Textile wearable (Digital textiles/e-textiles) – Smart textile prototype/ product developed by exploration/experimentation of embedding electronics in textiles for specific function
6. Digital crafts – Traditional crafts with embedded electronics
7. Social Intelligence - is the ability to successfully build relationships and navigate social environments. In this thesis, social intelligence pertaining to non-verbal expression through digital crafts is being studied.
8. Non-verbal Communication – Expression of emotions and feelings through external visual or tactile textures of wearables
9. Social Space – A defined area around the user, for eg. – Conference, Cafeteria, Library, etc. where user interactions are being studied for development of textile wearables
10. User Behavior – The science of understanding the way user interacts in social space which may or may not differ significantly from one another
11. Context – A specific use case where user behavior is being studied in a particular social space for the experiment
12. Expression – The way in which users interact/express in social space to convey a particular message
13. Socialization – Social interactions between individuals in person or on online portals
14. Definitions of Emotions
    i. Admiration - something regarded as impressive or worthy of respect.
    ii. Amazement - a feeling of great surprise or wonder.

iii. Joy - a feeling of great pleasure and happiness.
iv. Serenity - the state of being calm, peaceful, and untroubled.
v. Interest – excite the curiosity or attention of (someone); wanting to know or learn about something or someone.
vi. Awe – a feeling of reverential respect mixed with fear or wonder.
vii. Annoyance – the feeling or state of being annoyed; irritation; nuisance
viii. Boredom – the state of feeling bored.
ix. Sadness – the condition or quality of being sad.
x. Apprehension - anxiety or fear that something bad or unpleasant will happen.
xi. Anger - a strong feeling of annoyance, displeasure, or hostility
xii. Surprise – something unexpected or astonishing

Chapter 1

Digital crafts and their role in the Indian social space – An Introduction

This chapter states the background and need for present research, the frame work adopted and methodology in brief. The research questions which lead to corresponding objectives and hypotheses have also been mentioned. The contributions of this thesis have been reported along with a brief on the organization of the chapter contents.

1.1 Introduction

Textiles have a rich history, lineage and evolution in terms of their designs. They carry cultural traditions within their folds. Like every other mass manufactured product, textiles in India have a wide range of colors, textures, motifs, patterns and materials that are unique and contextual to Indian cultural milieu. Throughout centuries one can find traditional motifs, borders, embellishments, weave pattern and the like, being retained and continued with a sense of pride in India's visually rich ethnographical and cultural landscape. Textiles have been embedded with colors and motifs since prehistoric times to celebrate, protect or symbolize cultural beliefs (Veenu, et. al. 2016). They have been largely inspired from flora, fauna, architectural forms and everyday things. Entwined with the continuation of traditional designs are lives of the skilled craft makers for whom textiles are a source of work and livelihood.

Technological advancements, like elsewhere, has reduced avenues for growth for the craftsperson unless one is open to re-training and acquiring techniques that are more machine oriented. The threat of being displaced by electronics and machines is more true of craft makers who are involved in creation of textiles with patterns, colors, motifs, laces, weaving, stitching, etc. The textile industry in India is one of the largest source of employment generation with 45 million people involved in allied activities with a net worth of 150 billion USD (IBEF, 2018). It contributes 4% to the GDP and 14% to industrial production in India. The handloom sector employs 4.3 million people across the country being the second largest occupational sector after agriculture for the rural India (IBEF, 2018). Although the export from handloom sector was US$ 357.53 in 2016-17, handloom as a sector has been declining sharply (Ministry of Textiles, 2015) mainly due to the

following factors – low productivity compared to the mill sector, limited scope of technological upgradation, skilled workers migrating to other occupations, seasonal fluctuations, slow growth and production, low wages, work involves high physical activities and others. Over the last decade several government and NGOs have provided support for development, training programmes, advertising and facilitation of sale through local and export retailers which has resulted in better representation of the traditionally crafted products on retail and other platforms.

How can designers ensure the continuity of skills and livelihood while embracing technology is the question that motivates the exploratory research in this thesis. There are several state of the art examples such as Philips Bubelle dress (Bates, 2007), Galaxy dress (Cutecircuit, 2011), Nemo dress (Battista, 2012) and few from India such as IBM-Gaurav Gupta Saree gown (Singhania, 2017), Geometrica (Pankaj and Nidhi 2012) and *Luminocity* by Leconaet and Hemant (2013) that will be discussed in the following chapter. Although these designs are unique in terms of fashion statements and couture wear, they may need to be enriched so as to become a part of users' daily lifestyle and also augment user needs, such as for example communication, social expression, protection, education, healthcare, etc. To remain relevant fashion couture will need to become part of the emerging internet of things (IOT). The very use of e-textiles will open up new and interesting applications. The question facing the researchers is - Will such new applications be readily adapted by young Indian generation? Will the young Indian population, which is comfortable with today's smart devices, accept new e-textile applications, such as, for non-verbal communication, etc.? Will the early adopters of innovation also accept textile designs loaded with traditional signs and symbols, such as, motifs and patterns? We posit that India is a culturally diverse country and since users have diverse preferences, designing culture specific e-textile products could enrich the textile market segment for both the Indian and the global markets. In particular, it would offer ways and means to integrate traditional textile craft artisans' work with the promising new markets that are emerging out of embedding textiles with electronic capabilities.

With digital technology becoming part of daily lifestyle lifestyle (Quinn, 2010; Ariyatum et al.; 2005, Bardhan, n.d.; and, Schneiderman and Winton, 2016), textiles have become an interesting and useful medium for embedding, collecting and transmitting information in several domains such as health, sports, military, security, interiors, clothing, automobile, etc. E-textiles – which are essentially textiles with embedded electronics, will find interesting applications through artificial intelligence and Internet of Things (IOT) connected technologies by augmenting user lifestyles. E textiles have untapped design

potential for increasing their usability as mediums for interactions and communications in every day social space. Designing e-textiles or textile wearables will involve aspects such as usability, communicability and intractability for the wearer as well as for others in the wearers' environment, apart from functionality (Figure 1.1). This thesis addresses the missing blocks that exist between the traditional textile crafts and technological advancements pertaining to smart materials at present.

The research reported in this thesis finds its inspirations in the elaborate textile crafting traditions of India (Bhatnagar, 2004; Bhatnagar, 2005; Ambalal, 1987; Chisti, 2010; Gillow and Bernard, 2008; and, Katiyar, 2009) and an inquisitiveness to merge it with smart materials for context specific applications in the social space. Researchers believe that doing so could lead to preservation of hierarchical crafts and merge them with technologically advanced e-textile trends in the near future. The idea is to embed electronics seamlessly by reinforcing traditional design elements such as motifs, patterns, colors with smart materials to enhance the functions of a static traditional textile. It is posited that combining wearable technology with traditional crafts, designers can create contemporary products for context specific applications to bridge the gap between crafts, fashion, technology and user acceptance.

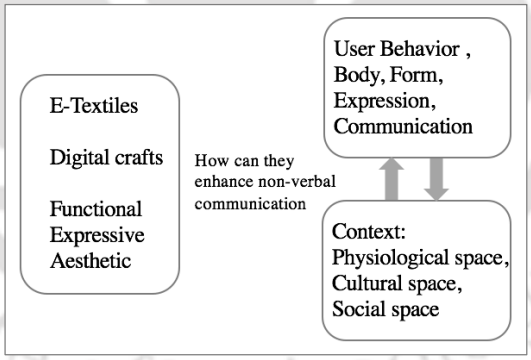


Figure 1.1: Digital crafts and social space being studied in this thesis

The user group mostly in focus is young students studying at graduate and post-graduate level (18-32 years) in a national technical institution and a national institution for fashion studies located in the north east of India. The purpose of targeting the age group of 18-32 years is the youth marketing trends (Warc, 2012) according to which 75% of Indian population is under 35 years of age, and this age group is more trendy, explores new products willingly and has the capacity to spend on newer products. Educational institutions comprise of students from varied backgrounds, in the series of studies

conducted, 55% respondents belonged to the East and North-East of India and 45% belonged to other parts of India. Thus, the young students provide substantial user demographic for studying preferences, opinion and evaluation studies being potential users of the emerging products.

1.2 Need for this research, Research Questions and Objectives

Not many researchers have explored and published work pertaining to e-textiles in India in comparison to extensive studies being conducted elsewhere. Few notable examples of LED fashion in India are that of the IBM cognitive LED saree gown designed by Gaurav Gupta (Singhania, 2017), LED fashion garments designed by Pankaj and Nidhi showcased at Wills India Lifestyle Week 2012 (Pankaj and Nidhi, 2012); and, *Luminocity*, LED dress designed by Leconaet and Hemant (Mistry, 2013). Huge potential lies in terms of merging traditional textiles and digital technologies to enhance connectedness of user lifestyles. Studies pertaining to cognitive aspects such as interconnections between – emotions, moods, opinion, judgement, personality and preferences of users could give rich insights considering the vast variations of textile crafts. A user centred design approach is needed to merge traditional crafts with digital technology to create culture specific products for both Indian and global markets. Understanding user behaviour of Indian population for designing wearables would be a pre-requisite of the user centred design process. Unique digital crafts are required to be explored considering the types of textile traditions, namely woven, painted, printed and embroidered. Each skill type could generate multitude of digitally unique interfaces. Such explorations have been found to be limited with respect to Indian textile craft traditions. Also, the capacity of textiles to evoke and express personality, opinion and communication is very unique in terms of non-verbal communication, as has been studied extensively by researchers elsewhere [Dolan, 2015; Moody, et al, 2009; Jiang and Liu, 2009]. Conducting such studies as discussed would bridge the gap that exists between craft, fashion, technology, user acceptance and craft research. Thus, this thesis lists down the following objectives to address the above-mentioned needs and research questions that will be addressed in the following chapters.
Figure 1.2 summarizes the focus and contributions of this thesis derived out of three broader sub-domains – Traditional textiles of India, Smart technology and the Social space of the users. In the following chapters, it will be elaborated, how segment 1 probes understanding of the users and their perceptions, implications of which led to designing of digital craft prototypes in segment 2. And further, two experimental studies were conducted

to test hypothesis and formulate design heuristics of digital crafts emerged out of traditional craft practices, segment 3.

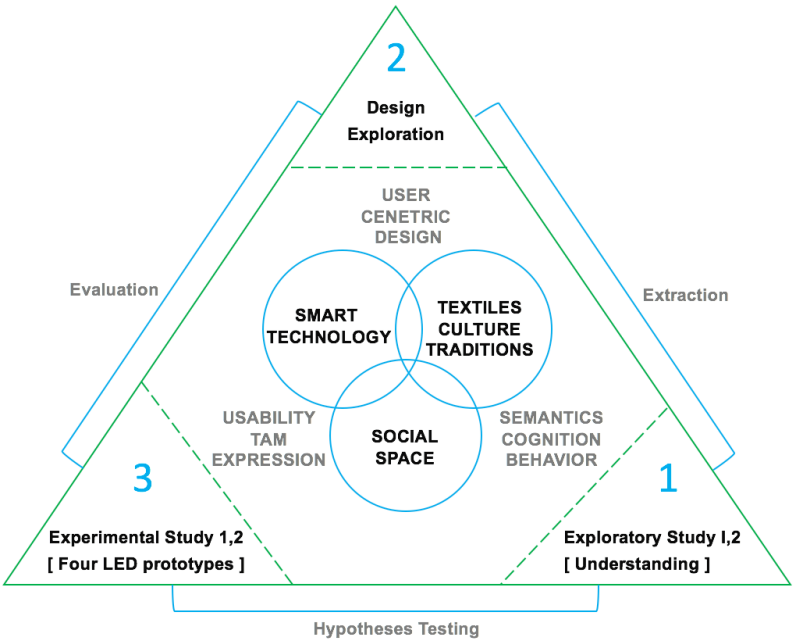


Figure 1.2: Research Frame

The research questions being addressed in this thesis are – (i) How do traditional textiles influence and evoke emotions, opinion, judgement and personality traits among young users? (ii) What are behavioural aspects of users that could influence designing of textile wearables? (iii) What are the ways in which smart materials could be seamlessly embedded with traditional textiles for augmenting functions targeted at young users? (iv) Are there possibilities of enhancing self-expression and non-verbal communication through digital textiles in the social space, if so how can they be captured and quantified? They will be explained and elaborated in section 2.7.

To answer the above research questions, the following objectives have been posed. (i) To understand the (a) perception, (b) preferences, (c) opinion, and, (d) emotional evoked in users pertaining to traditional textiles of India that could contribute to designing textile wearables. (ii) To probe user behavior in social space based on behavioural studies that contribute to designing of textile wearables in terms of (a) boundaries users create around themselves, (b) emotions expressed in certain contexts, and, (c) comfort levels experienced with different kinds of individuals. (iii) To explore integration of traditional and digital textiles that could enhance non-verbal communication. For this, first, exploration of different textile crafts and technological elements that could be integrated seamlessly to create a series of digital craft prototypes has been carried out. And then, secondly, evaluate

them on parameters of non-verbal expression based on cognitive studies of moods, emotions, feelings, personality and preferences along with usability evaluation and technological acceptance studies. (iv) To propose a design heuristic framework for designing digital crafts derived from traditional textile craft practices of India based on traditional textile motif vocabulary.

1.3 Research Methodology and Experiment Design

A qualitative and quantitative explanatory research methodology was adopted. Empirical data was collected to test and validate the three hypotheses and the theoretical model of non-verbal self-expression using LED embedded prototypes in the social space of the users. The research leads to proposition of a design heuristic framework for designing digitally crafted wearables derived from traditional textile crafts of India. The research methodology followed has been depicted in Figure 1.3, this will be elaborated in detail in Chapter 3.

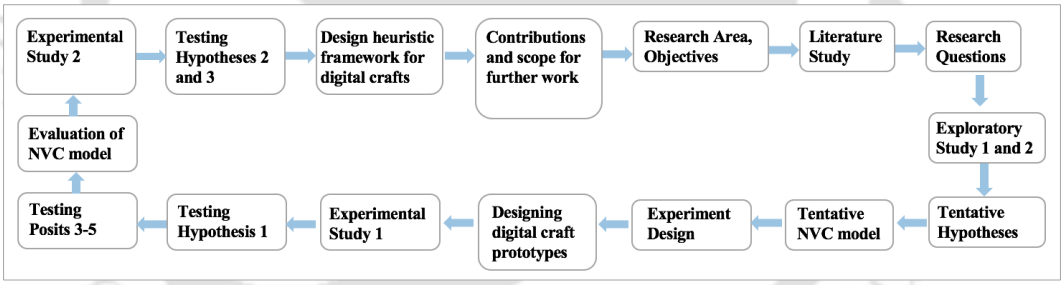


Figure 1.3: Research Methodology

The research flow has been elaborated in Figure 1.4. The first Exploratory study was a photo elicitation (Richard, et al., 2015) based cultural probe carried out to understand perceptions of young female users about traditional textiles of India, their opinions, cultural connotations pertaining to motifs and colors, personality traits and emotions evoked in them upon viewing a set of sarees which led to testing of Posit 1. Exploratory study 2 was a behavioural study aimed to understand young users and the boundaries they create around themselves for sharing information, the comfort levels experienced in sharing information with different categories of individuals and emotions experienced in different social spaces or contexts, which led to testing of posit 2. The data was collated into deriving insights to initiate and carry out the user-centered design process for designing digital crafts based on

traditional textiles of India; formulating tentative hypothesis and tentative theoretical model for non-verbal expression though digital crafts in social space of users.

Three LED embedded scarves were designed and evaluated during Experimental study 1 where one hypothesis and posits 3-5 were tested. The three posits led to evaluation and validation of the theoretical model for non-verbal expression though digital crafts in social space of users based on correlations between emotions, aesthetics and non-verbal communication and its effect on technology acceptance, i.e., acceptance of LED based digital crafts by the young respondents; which will be elaborated in section 4.5 and 5.2.2. A LED embedded traditional jacket, *bundi*, was designed for evaluation of Hypotheses 2 and 3 during Experiment 2 which tested the role of digital craft, LED embedded *bundi*, for non-verbal expression in the social space of young respondents. The social space is defined as a defined area around the user, for example – Cafeteria, Library, School, Park, Commuting, etc. where user interactions are being studied for development of textile wearables.

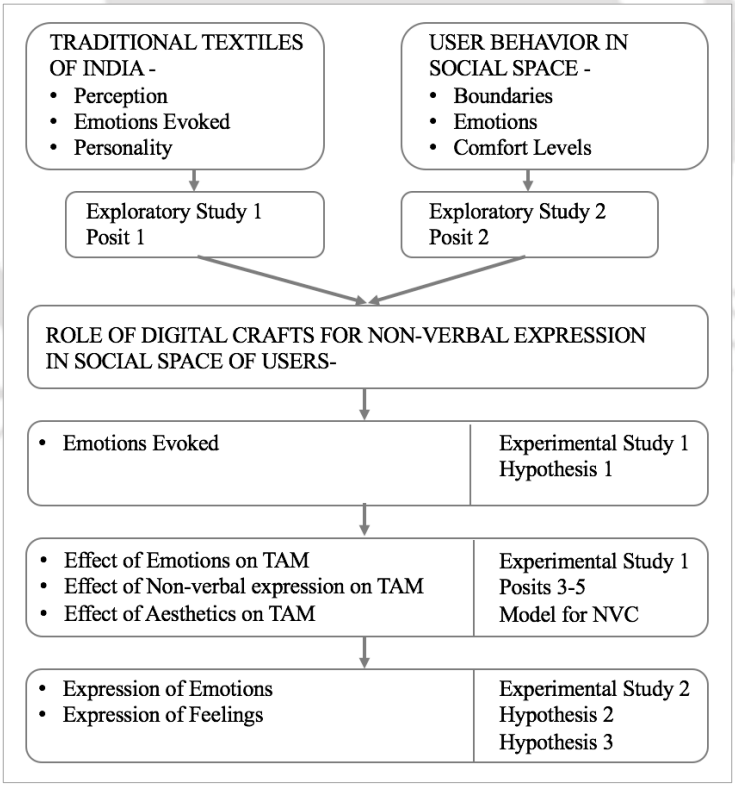


Figure 1.4: Research Flow Diagram

Following are the 5 posits and 3 hypotheses being evaluated though the research. Posits 1 and 2 were evaluated in Exploratory studies 1 and 2.

Posit 1: Traditional textiles positively influence emotions, personality, attitude, opinion, preferences and self-expression among young female users in India.

Researchers have studied that clothing, personality, opinion, moods are closely related (Dolan, 2015, Moody et al., 2009, and Xiang and Jiu, 2009). However, such studies are sparse in terms of traditional textile crafts and clothing of India. Thus, Posit 1 seeks to understand user perceptions about traditional textiles and inter-connectedness of moods-emotions- colors and personality through a cultural probe.

Posit 2 - Significant levels of emotions, feelings, boundaries and comfort levels are experienced by users in a social space

Behavioural studies are important prior to design in a user centric design process. Studies pertaining to young Indian respondents and their behaviour in social space are limited, hence the posit probes into boundaries, emotions experienced and comfort levels of young respondents that could lead to designing to textile wearables.

Posits 3-5 are being tested through experimental study 1 and lead to evaluation of theoretical model for non-verbal expression though digital crafts in social space of users. The objective is to understand the effect of variables of positive emotions, negative emotions, aesthetics and attributes measuring non-verbal expression on the acceptance of technology being experimented with. The findings indicate the inclination of young users of using the digital crafts prototypes based on the variables being measured.

Posit 3 - Traditionally crafted wearables strongly influence positive and negative emotions leading to high perceived usefulness and perceived ease of use.

Leads to correlations between positive and negative emotions with respect to technology acceptance (Davis, 1989) of the digital craft prototypes which lead to affirmation of the theoretical NVC theoretical model proposed and validated in Chapter 4 (Figure 4.35).

Posit 4 - Aesthetics has significant effect on technology acceptance - perceived usefulness and perceived ease of use for traditionally crafted wearables

Assesses the roles of aesthetics of the digital craft prototypes on technology acceptance among users which leads to correlational significance for the theoretical NVC model of non-verbal self-expression in social space using digital craft wearables (Figure 4.35).

Posit 5 - Traditionally crafted wearables significantly enhance non-verbal expression among users in a given social space leading to high perceived usefulness and perceived ease of use

Analyses the role of variables measuring non-verbal self-expression in the social space of user for the given contexts with respect to technology acceptance which signifies correlations in the theoretical NVC model (Figure 4.35)

Following are the three hypotheses, Hypothesis 1 is being tested in Experimental study 1 and Hypotheses 2 and 3 are being tested in Experimental study 2.

H1 – Traditionally crafted textile wearables evoke positive emotions strongly in users than negative emotions.

Hypothesis 1 is an extension of Posit 3 to affirm that positive emotions are evoked higher by digital crafts through a comparative assessment of three digitally crafted prototype scarves. Hypothesis 1 is being tested in Experimental study 1.

H2 - Digital textiles evoke emotions significantly in the social space of users than static textiles

Hypothesis 2 evaluates the capacity of textiles to evoke emotions explicitly yet subtly in users around them in the social space through a comparative study of static with dynamic prototypes to assess the effectiveness of a dynamic prototype in evoking emotions through visual cues that could lead to better non-verbal expression when required.

H3 - Digital textiles enable users to significantly express feelings in their social space than static textiles.

Hypothesis 3 evaluates the capacity of dynamic textiles over static textiles in conveying specific feelings through visual cues of a dynamic prototype to other users in the same social space to establish a better decorum via non-verbal self-expression when needed.

1.4 Thesis Contributions

As studied in literature, few designers in India have explored the domain of digital crafts and usability and acceptance studies are limited with respect to young Indian respondents which comprise 75% of the population with respect to textile wearables, this

thesis attempts to address few missing blocks between crafts, fashion, wearables and scientific research in India. Following are few contributions that have emerged from this thesis.

1.4.1 Potential of merging traditional textiles of India with wearable technology

Four digitally crafted textile wearables have been designed and tested with 274 young respondents in total. Apart from this 3-6 variations of digital craft explorations have been reported in this thesis. These examples demonstrate the capacity of traditional textile crafts to seamlessly embed electronics within their motifs and patterns to become dynamic. The dynamicity could have several implications in different use cases, one of which is non-verbal self-expression, which has been experimented with in detail in the thesis.

1.4.2 User centric design process and acceptance of digital crafts by young users of India

The process of designing of digital crafts has been explicitly user centric. First, user behaviour and perceptions of traditional textiles were understood through two exploratory studies which laid foundation for designing textile wearables. Further, two experimental studies were conducted with three similar scarves and an LED jacket which were capable of changing colors, i.e., visual cues for more meanings that could be conveyed than the static textiles. User evaluation and design iteration blended together to yield the digital craft wearables designed. The experimentation for non-verbal self-expression using digital craft prototypes and studies on technology acceptance and usability assessment with positive results demonstrate a method of scientific evaluation of digital crafts and the optimistic response of young users towards accepting such crafts for specific purposes.

1.4.3 A new measure for measuring non-verbal expression through digital crafts in the social space of users

A set of 7 variables for measurement of non-verbal expression through digital crafts have been derived from Daniel Goleman's Social Intelligence (Goleman, 2006). The variables were captured on a 5-point semantic differential scale and a replicated experimental methodology was followed with three LED embedded scarves for validation. The results of Principal Component Analysis on SPSS reported that that the factors loaded

together repetitively for the three LED scarves. The variables capture the experience of respondents in Experimental Study 1 in terms of effective, understandable and easy non-verbal expression through color changing visual cues of the three LED embedded scarves.

1.4.4 Design heuristic framework for digital crafts

A design heuristic framework has been positioned in Chapter 6 of the thesis where the process of deriving elements of traditional textile crafts has been merged with embedded electronic components which has been largely followed in this thesis. The motif vocabulary reported along with possibilities of integrating embedded electronics, with examples of the prototypes that have been designed during the research work demonstrate a unique way of designing culture specific textile interfaces for both the Indian and the global user segments. The framework recommends designers in similar subject areas to refer to for design and scientific evaluation of digital crafts.

1.5 Organization of the Thesis

Figure 1.5 elaborates the chapterisation and contents of thesis writing carried out for present research. There are 6 chapters – Introduction, Study of Literature, Research Methodology, Findings of Exploratory studies and Implications in Design, Findings of Experimental Studies, and, Discussions followed by References and Annexure.

Chapter 2 reviews published literature in five sub-domains of interactive textiles, traditional textiles of India, cognitive psychology pertaining to textiles, craft research and design semantics. The chapter identifies gaps from the literature studied, lists down research questions and corresponding objectives to be addressed in this thesis.

Chapter 3 reports the qualitative and quantitative explanatory research methodology followed to conduct two exploratory studies and two experimental studies for evaluating 5 posits, a theoretical model for non-verbal expression with digital craft wearables in the social space of users and three hypotheses. The experimental set up, procedure, tools used, sample size and methods of analysis have been explained in detail.

Chapter 4 reports the findings of Exploratory study 1 and 2 and their implications on design of digital textile craft wearables. Exploratory study 1 was conducted with 60 young

female respondents about Perceptions of young users about traditional textiles. Exploratory study 2 was conducted with 30 young respondents that probed Behaviour of young users in social space in terms of boundaries, comfort levels and emotions. Two posits were evaluated in through the exploratory studies. The user centric design process of crafting the four textile wearable prototypes has been elaborated upon.

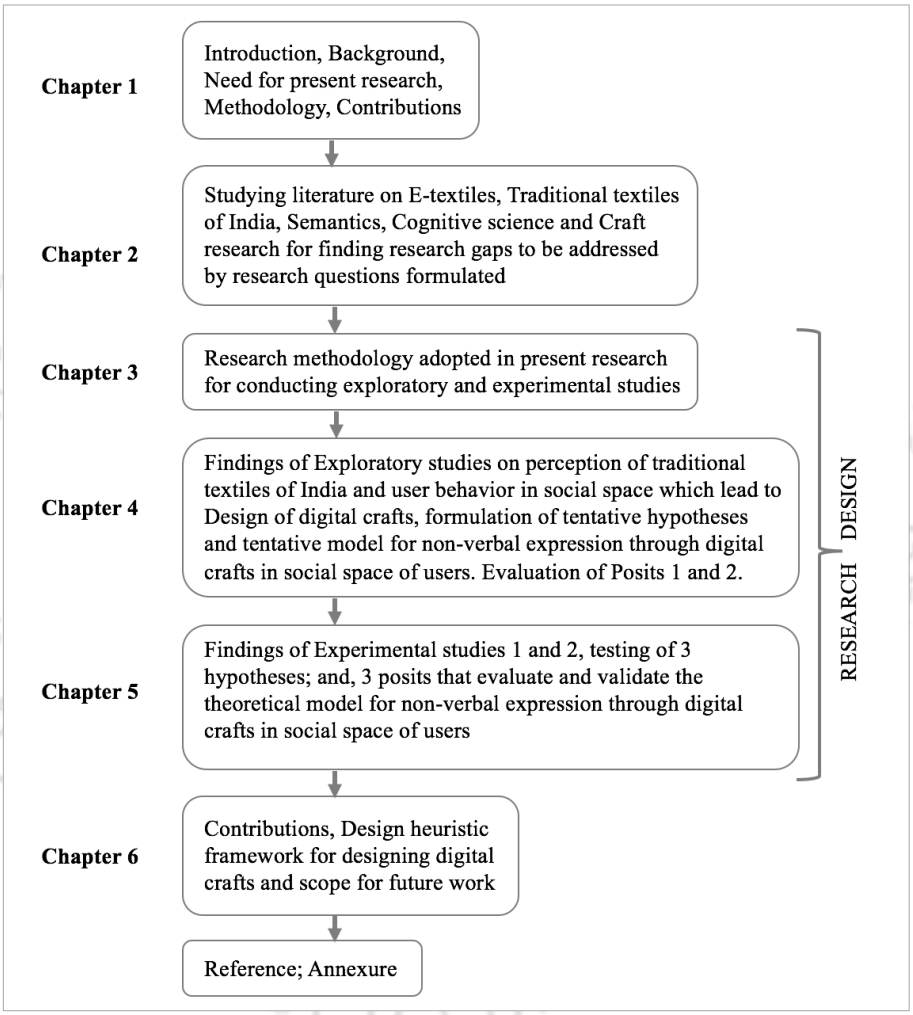


Figure 1.5: Chapterisation and contents of this thesis

Chapter 5 reports evaluation of 3 posits, a theoretical model of non-verbal self-expression using LED embedded prototypes in the social space of the users and two hypotheses testing and validation via two experimental studies wherein 184 respondents participated in total. The chapter also validates seven variables for measuring non-verbal self-expression using digital craft wearables through Principal Component Analysis.

Chapter 6 presents discussions of the research work conducted, a design heuristic framework and motif vocabulary positioned for researchers in similar domain to refer to. The chapter also discusses a summary of contribution, few limitations and scope for further work on similar research studies.

Chapter Summary: *This chapter introduces the background for present research, the need for conducting this research, research questions and objectives to be addressed and the methodology and experimental design in brief. The contributions of this thesis have also been presented along with a brief overview of organization of the following chapters. Study of relevant literature and the gaps identified will be reported in detail in the next chapter.*

Chapter 2

Literature Study

This chapter reviews existing literature from over 180 sources, of which 120 are being reported, in five connected sub-domains of – electronic textiles, traditional textiles of India, design semantics, user experience design pertaining to textiles and related research methods for interactive textiles. The chapter summarizes into implications of literature studied in designing digital crafts and gaps to be addressed through present research.

2.1 Introduction

Published sources of literature, Research papers (35<), Books and book chapters (15<), Patents (03<), Journals (20<), web articles (20<) and websites (30<) were studied under five different categories as described with keywords in Figure 2.1. These five sub-domains were intended to contribute towards understanding traditional crafting skills, selecting relevant crafts to embed electronics as studied in the electronic textile segment and conducting user evaluation as studied in research methods. The analysis of traditional textiles and digital crafts to be designed as part of this research has been conducted via semantic study. Craft research, research methodology and behavioral aspects related to textiles were studied to plan user studies to be conducted prior to design and post-design stage for experimental evaluation of digital crafts to be prototyped. The five sub-domains have been described in following subsections and the chapter summarizes into identification of needs and the gaps identified from literature study to be addressed in this research.

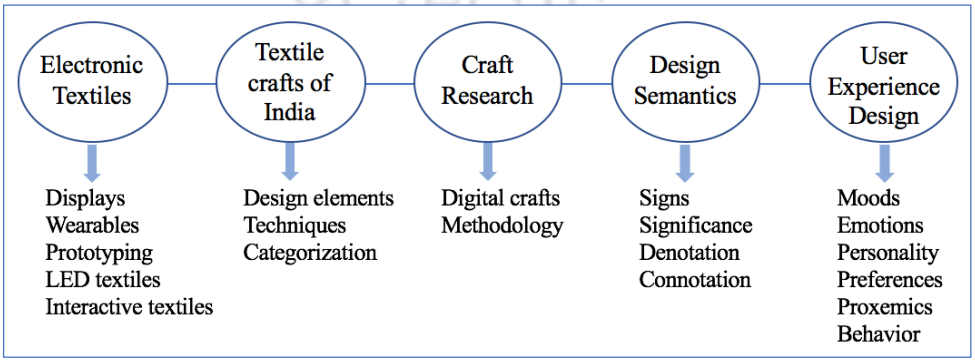


Figure 2.1: Categories and Keywords for literature study

2.2 Literature study on Electronic textiles

The last two decades has seen increased research in the sector of smart textiles that brings together multiple disciplines of Textiles, Electronics, Information Technology, Communication, Materials, Biotechnology, Nanotechnology, Microsystems, Manufacturing, Design, Ergonomics, Fashion, to mention a few for making functional wearable smart textiles (Quinn, 2010). Applications of smart textiles have been gainfully researched for medical, military, bio-monitoring, safety, ambient living, assisted living, sports, performance, automobile, entertainment, advertising and other fields. Figure 2.2 presents a brief timeline of electronic textile development globally. The timeline is not comprehensive but presents an overview in terms of few significant examples.

Mili John Tharakan in 'NEOCRAFT- Exploring Smart Textiles' at the conference 'Ambience', 2011, explains that smart textiles are in a stage of transition. When they are made digital, responsive and smart – do they become a new gadget? If they become a gadget, do they satisfy our senses as crafts or as gadgets? The traditional textile craft processes are known for their lengthy process of making. The beauty is about elaborate processes involved that enhance the quality of the product. Once the product is used over time, it embeds memories in it and is passed on to next generation as a memoir of the rich heritage. Certain textiles such as *pabu ji ki phad, mata ni pachedi,* etc. have religious value embedded in them. This makes textiles powerful, spiritual and beautiful. The need is to find a balance between the crafts and the tools available as the changes are happening too fast. So, the craft of smart textiles needs to incorporate values and memories so that they can become as important as traditional artefacts owned by the users.

Wearable computer, as described by Steve Mann, is a data processing system attached to the body, where input allows functionality of the system to be modified and output can be constantly monitored despite the shift in body position or task (Loomia, 2016). Hertleer and Langerhove (2004) define smart textiles as textiles that sense stimulus/ stimuli from the environment, can react and adapt to the stimulus through electrical, Thermal, Chemical, magnetic or other means. Smart Textiles have been broadly classified as – Passive, Active and Ultra smart. Passive Smart materials (first generation materials) have sensors embedded in them that enables to sense external stimuli. Active Smart materials (second generation materials) comprise of a system of sensor and actuator that enable sensing and reacting to the stimuli. While, ultra-smart materials (third generation materials) can sense, react and adapt to the external stimuli.

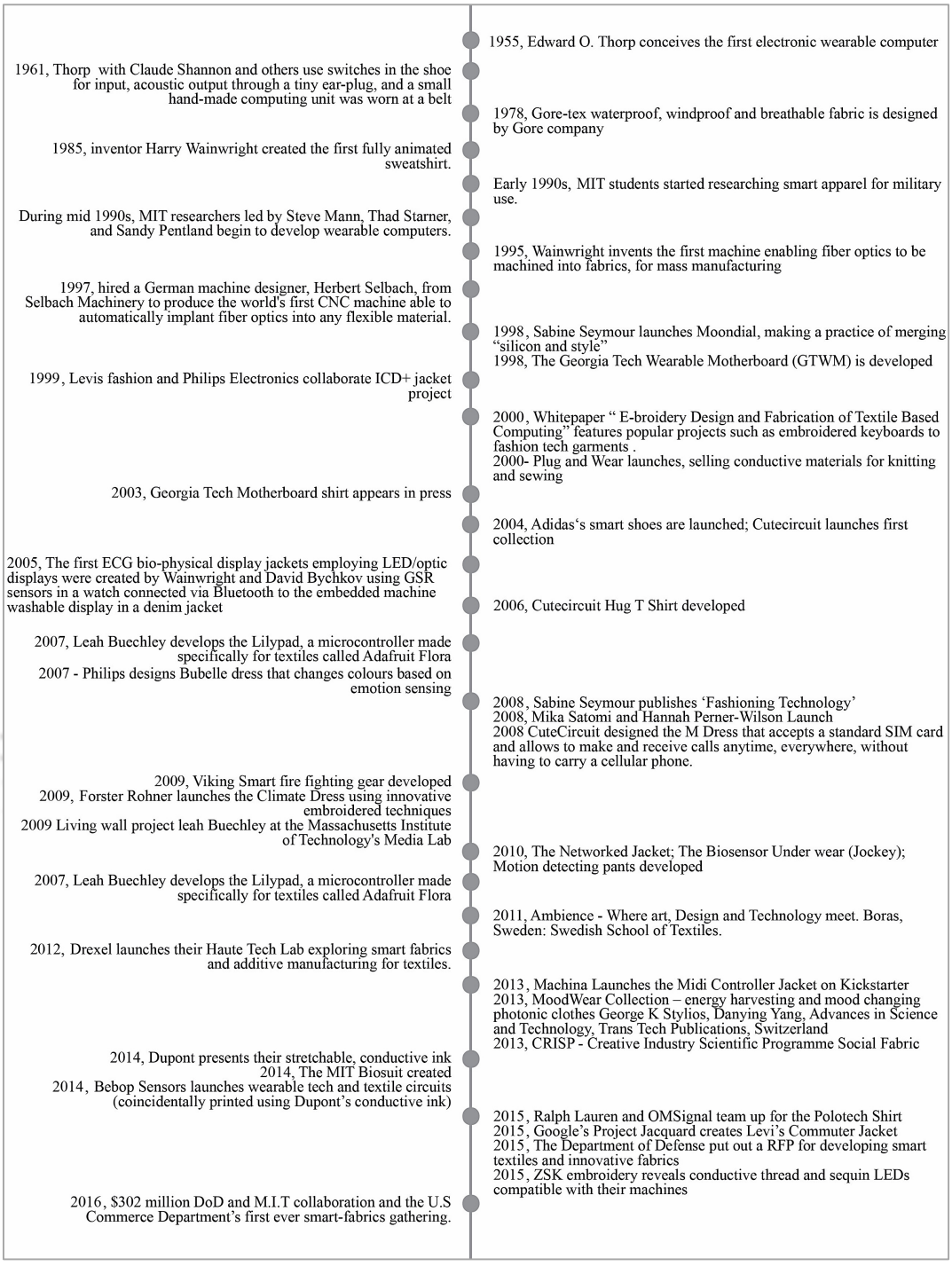


Figure 2.2: Brief Timeline of developments in smart textiles globally over six decades (Deepshikha, et al., 2017)

The following sub-sections 2.2.1 and 2.2.2 mention examples of smart textiles and LED enhanced textiles. An example of bio-engineered textile has also been mentioned. Sub-

section 2.2.3 discusses implications of these state of art examples on the textile crafts of India and possibilities that lie ahead.

2.2.1 Smart textile examples

Parkova et al. (2014) in their patent *Flexible light-emitting textile display with floats for covering electronic devices* experiment flexible LEDs arranged in warp and weft yarns where each LED is individually controlled. Voltage required by the system depends on the number of LEDs being lit up at the same time. Patent *Gestures for Interactive Textiles* by Schwesig et al. (2016) comprises a gesture manager which is wirelessly coupled to an interactive textile. A computing device with memorised instructions analyses touch data to identify gesture and initiate a functionality of the computing device based on gesture input and context. Researchers from Georgia Tech Research Corporation have patented a flexible information infrastructure integrated within the fabric for collecting, processing, transmitting and receiving information. Plastic optical fibers can detect projectile penetration and act as data bus or motherboard for transferring information. The fabric can be used to interact with the environment (e.g., lighting, music, climate, etc.) or specific tasks such as switching on/off appliances (Jayaraman, et al. 2002).

Inoue, et al., report development of highly conductive inks which can be employed for designing smart textiles using stretchable elastomers containing metallic fillers. In their experiments, bio-signal monitoring was performed successfully. Such inks could be explored to design painted and printed textile crafts, as an augmentation to traditional skills. Jane Mccann (2005) points out that a gap exists between aesthetic, technical and cultural needs and identification of end-users needs based on cultural and aesthetic preferences could enrich design processes. Investigators have designed historical textile artefacts in a museum with haptic, visual and auditory feedback for users to interact and navigate themselves (Taylor, 2012).

Researchers have designed Moodwear smart suits based on solar harvesting smart photonic system. The colors change based on moods of wearer using luminescent woven fabrics and flexible photovoltaics (Stylios, 2013). Singh, et al. (2011) have described ten bio-inspired approaches to designing smart fabrics with relevant examples and distinct design processes. Baurley (2004) and Kirstein (2013) mentions the future of hybrid industries and ubiquitous intelligence where products that will lead in the market will be those which enhance the quality of users' life. Experience economy, sensory sciences and seamless integration of intelligence with products will form an important part of future research.

Oerlikon in its press release (Barmag and Neumag, 2015) for Techtextile 2015, Frankfurt, mentions that textiles for automobiles in near future may employ conductive fabrics for cooling and heating, responsive textile panels that can convert gestures to gear shifting, bio-monitoring of driver or passengers and other applications. Researchers have explored the role of textiles in evoking aesthetic pleasure (Buechley, 2008 and Taylor and Robertson, 2014), emotions (Devendorf, et al., 2016; Hallnas and Redstorm, 2001; and, Davis, 2015), interaction with wearers environment (Loop.ph, 2006), social interactions (Kan, 2015) and several other scenarios. Researchers have also studied the relevance of point lights and their role (Harrison, et al., 2012).

Christl Lauterbach, Axel Steinhage, Axel Techmer have designed Large-area wireless sensor system based on smart textiles that calculates trajectories, distinguishes between footsteps and fall and is suitable for Ambient Assisted Living - automatic door opening and closing, alarm on intrusion and activity monitoring (Lauterbach, et al., 2012; Figure 2.3).

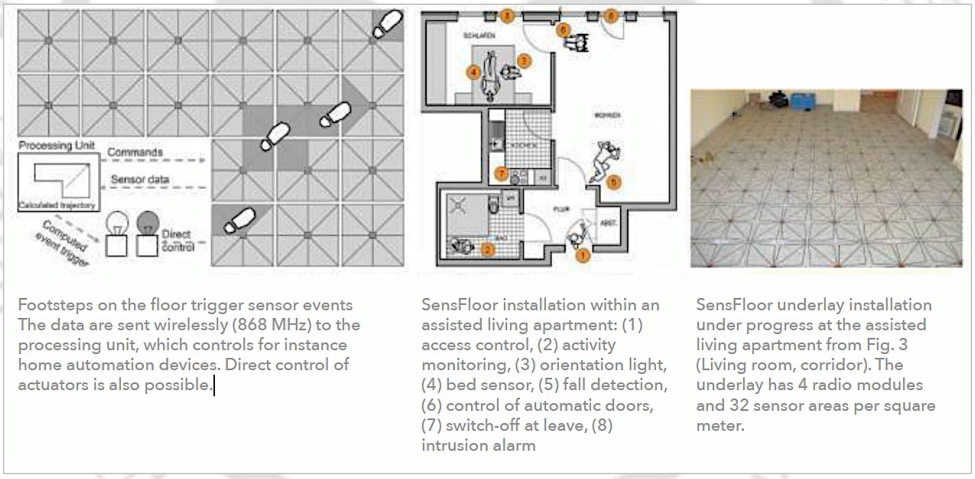


Figure 2.3: Large-area wireless sensor system based on smart textiles (Lauterbach, et al., 2012)

Digital Dawn (Figure 2.4) designed and developed by London based studio Loop.pH comprises biomimetic installation that monitors environmental lighting condition and accordingly lights up the wallpaper. The darker the room, the brighter the wallpaper lights up itself. This is targeted for sufferers of SAD (Seasonal Affective Disorder) syndrome and also for ambient living. Emulation of the natural process of photosynthesis using printed electronic technology aims to explore the impact of changing lighting conditions on the users' sense of well-being (Loop.ph, 2003).

Sonumbra (Figure 2.5) developed by London based studio Loop.pH is world's first responsive lace architectural work. It comprises electroluminescent wires creating a canopy

which change patterns as people move underneath it. For the Aldeburgh Festival, 2007 musical harmonies and rhythms also changed along with light patterns as viewers moved around the installation to become a part of the composition of light, sound and space (Loop.ph, 2006).

Living Wall (Figure 2.6) designed by a group of MIT researchers led by Leah Buechley is an interactive wallpaper painted with magnetic, resistive and conductive paints (Buechley, 2010 and Buechley, et al., 2008). The painted surface creates a passive circuitry which along with microcontrollers, light, temperature, colour sensors and nitinol wire attached to flowers, and a wireless module, help the user to light up the wallpaper upon being touched and play pre-programmed music. The project has extended application in ambient information display along with lighting, environmental sensing and controlling appliances.

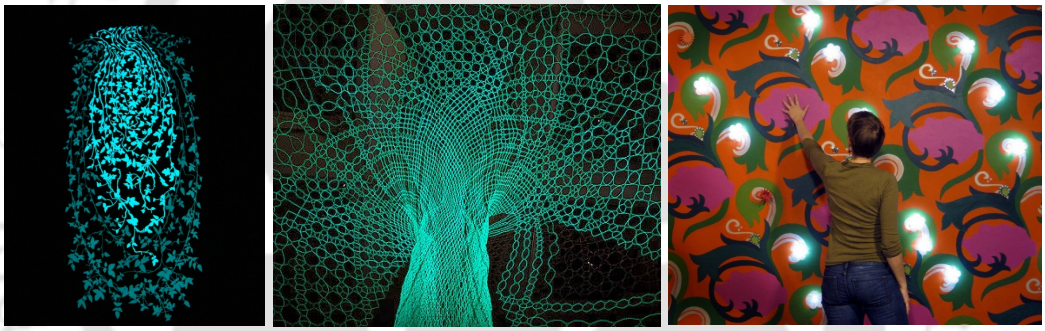


Figure 2.4: Digital Dawn; **Figure 2.5:** Sonumbra; **Figure 2.6:** Living Wall

Researchers from University of Laval under the supervision of Younès Messaddeq have created a handwoven smart fabric comprising of layers of copper, polymers, glass and silver that form a sensor and antenna (The Engineer, 2014). It is capable of biomonitoring human body and sending information through wireless networks (Figure 2.7). Such fabric could find application for security personnel, elderly living alone, patients suffering from chronic diseases, apart from others.

Project Kino (Figure 2.8) explores possibilities of futuristic dynamic accessories using miniaturised robots developed by researchers at the MIT Media Lab (Kao, 2017). Individual elements become a part of shape changing jewellery according to the occasion its being worn to. It has also been applied to climate reactive clothing where robots can help put the hood on or off the jacket according to the user's requirement.

Holographic fashion show (Figure 2.9) was designed to showcase haute couture collection of designer Stefan Eckert in Hamburg, 2011 (Kopekin, 2017). Alexander McQueen had earlier used a hologram of Kate Moss in 2006. Eckert's show was an innovative installation

that showcased pre-filmed footage of models and pre-arranged effects to create hologram on stage instead of runway models synched with music and visual effects to create an optical illusion.



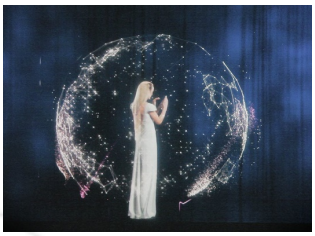


Figure 2.7: Handloom woven smart textile; **Figure 2.8:** Kino, MIT; **Figure 2.9:** Fashion holography

Handwoven fabric designed by researchers from University of Laval, primarily measures body's physiological parameters. The research describes in detail the innovation in creation of sensor as threads that can be woven in the fabric while weaving. User study with such a fabric, accuracy of measurements across a day, across different age groups and during different types of tasks being performed by the users, needs to be calibrated.

Project Kino explores innovative accessories and shows its application in drawing a hood on-off the jacket. The size of the robots could be miniaturised; shapes and forms of accessory could be explored with those of traditional jewellery and other accessories of India and further user trial based on need and use cases could provide insights into the working of the dynamic system. The holographic fashion show requires expert handling, time intensive conception and execution, expensive developmental process. It is more suited for couture than ready to wear garments or everyday accessories. Researchers could integrate holography into textiles for functionality added to aesthetics in a context based design approach.

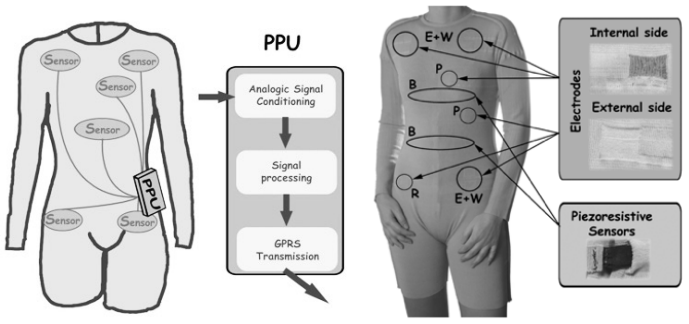


Figure 2.10: WEALTHY; **Figure 2.11:** Soldier wearing smart uniform

WEALTHY (Figure 2.10) is a health monitoring system for cardio-vascular diseases comprising sensors and electrodes with advanced signal processing capabilities for real time assessment (Paradiso, 2005). Figure 2.11 depicts Military uniform with e-textiles by BAE Broardsword (Trenholm, 2015) comprising woven smart threads, embedded computer for power and data, embedded battery storage with flexible charger, fabric mounted connectors in customer defined locations, head mounted displays and other wearables connected with the uniform for wireless transmission of data to the control station.



Figure 2.12: Textales – CRISP; **Figure 2.13:** Bubelle dress; **Figure 2.14:** Biolace

Textales (Kuusk, 2011) has embedded fairy-tale application on the bedsheet for children's edutainment (Figure 2.12). Textales has been developed as part of series of smart textile products by the Creative Industry Scientific Programme, a Dutch government funded initiative that collaborated with industrial and scientific partners. Philips Bubelle dress (Figure 2.13) was developed in 2007 based on emotion sensing (Bates, 2007). The inner layer comprises sensors which change the colour of the outer layer of the textile. Philips aimed to create garment that is more *sensitive* than *intelligent* by changing light colour based on changes in body's physiological parameters (temperature, sweat, etc.) due to change in emotional stress, arousal or fear.

Biolace (Figure 2.14) is an example of bio-engineered lace designed by Carol Collet (Central Saint Martins College, UAL, London) which uses synthetic biology for cultivating textiles from plants by reprograming genetic code for a futuristic scenario from 2050 where sustainable manufacturing becomes a necessity for an overpopulated planet (Collet, 2013). The example figure has a lace growing on strawberry plant, other examples of the project include laces being grown on Basil, Spinach and Tomato which are suitable for several purposes such as – UV protection, Protein C edible lace, Luxury fashion trimmings, culinary herb and anti-viral medicine.

2.2.2 LED enhanced textile examples

From the many trends studied, we describe a few examples of design experimentation in Fashion and Textiles with embedded LEDs. Galaxy dress (Figure 2.15) designed by Cutecircuit comprises of 24000 colour pixels embroidered on a layer of silk to make the world's largest wearable. The luminous fabric moves with fluidity and lightness like normal fabric and has 4 layers of silk chiffon to diffuse light. iPod batteries power the display for 30 minutes to one hour thus enabling easier movements for the user. The areas without light display is covered with 4000 hand embroidered Swarovski crystals for the dress to look appealing even when the display is off display (Cutecircuit, 2011). It has been kept in exhibition for display and has applicability for being worn as an evening gowns, mostly a part of couture fashion.

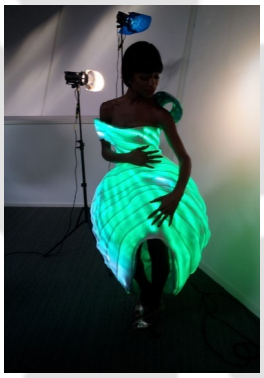



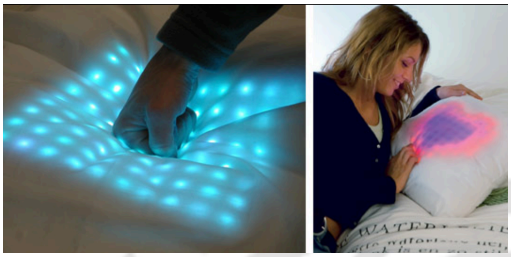

Figure 2.15: Galaxy dress; **Figure 2.16:** Nemo dress; **Figure 2.17:** Easyjet Uniform

Nemo dress (Figure 2.16) designed by Designer Leon Klaassen Bos has a retro-futuristic haute couture silhouette and comprises of 2000 LED lights controlled by a compact computer (Battista, 2012). The shape is inspired from an inverted droplet of water, the volume of which gives enough space for the technical components to fit in. The layers move with body movement slightly likes waves in the water. Interestingly, the colour changes according to the colour of the dress of the viewer in front of it. The dress has been designed for playfulness and sensuality while also being modern and elegant.

For a British airline carrier, Easyjet (Figure 2.17), Cutecircuit has designed LED based uniform that provides the cabin crew with extra lighting, a lapel that displays flight information and built-in microphone for easier communication between the crew members (Gil, 2015).

Philips showcased photonic textile products at the IFA Consumer Electronics Fair in Berlin, 2005 where multi-colored LEDs are integrated as flexible arrays to which enables

display of programmable patterns while still retaining the softness of the textile material (Inhabitat, 2005; Figure 2.18). Researchers at MIT have developed fine fibres with embedded electronics, the LEDs embedded are small enough to pass through the eye of a needle (Chandler, 2018; Figure 2.19).



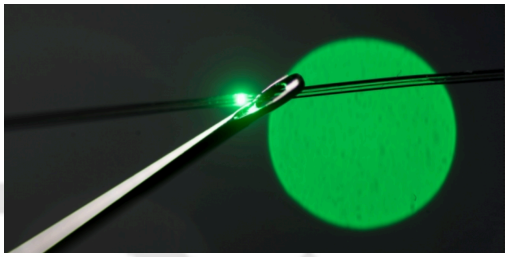


Figure 2.18: Philips LED textiles; **Figure 2.19:** MIT LED fibre

Jasna Rok designed *Fashion on Brainwaves* at Ghent University where textile clothing masks the wearer and changes colors based on the wearer's brain activity (Joosting, 2016; Figure 2.20). Karolina Kurkova wore IBM-Marchesa for Met Gala 2016 (Colon, 2016; Figure 2.21). The LEDs integrated in the dress reflected the sentiments of the incoming twitter feeds being wirelessly analysed by Watson. Figure 2.22 depicts interactive particle physics dress with LEDs and IBM Bluemix designed and worn by designer Chung Hay Luk in 2015 (Shenova, 2015). Mary Huang a designer from UCLA designed *Rhyme and Reason*, a collection based on LED lights under different layers of fabrics with an invisible finish and removable batteries that light up for 10 hours at a time (Huang, 2009; Figure 2.23).

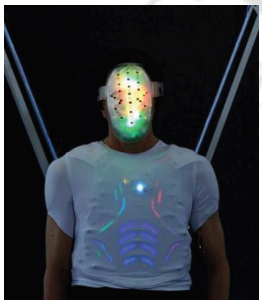


Figure 2.20: Jasna Rok *Brainwaves*; **Figure 2.21:** IBM-Marchesa 2016; **Figure 2.22:** Chung Hay Luk 2015; **Figure 2.23:** Mary Huang - *Rhyme and Reason*

The literature study was conducted prior to the studies conducted, alongside and is ongoing. The purpose of studying literature at the beginning was to study as many different domains for understanding several possibilities that the chosen subject could manifest itself into, to

find connections between related and un-related domains, even before the basic plan for conducting research started, so that, digital crafts could possibly become diverse for suitable applications by incorporating technology wherever possible/needed suitably. A researcher, in future, could glance at the various possibilities which section 2.2 reports with its diverse examples – robotics, genetics, electronics, etc. The literature study was planned to be studied broadly and then specifically for the related experiments to narrow down the focus of research subject. As the research progressed, feasibility of prototypes and portability were key concerns that led to designing LED based textiles. Figure 4.20 (and section 4.4.1) explain that it was intended to incorporate 3 different forms and functions but eventually 3 LED embedded scarves were designed for comparative study, Figures 4.21-4.26. The following sub-section discusses the implications of literature studied above with respect to the context of India and the possibilities of exploring digital crafts as exclusive cultural artefacts.

2.2.3 Implications for designing handcrafted e-textiles of India

Wearable electronics such as Lilypad Arduino, conductive threads, sew-able micro LEDs, conductive inks, sensors, temperature sensitive inks, etc. can be integrated with traditional designs seamlessly to create technologically competent products. Such products need not be mass produced on looms or by artisans, but may be designed and developed as a specific line of products by design studios, brands, NGOs etc. or initiated by the government as upgradation programmes. For example, block printed fabrics may be developed with thermo-chromic pigments that could change patterns with change in temperature. Sensor strips could be woven with the handloom yarns as warp or weft for conductive handloom woven textiles. As depicted in Figure 2.25 - a handloom woven fabric has been developed by researchers at University of Laval for bio-monitoring and military applications. In Figure 2.24, researchers have woven flexible plastic strips to embed LEDs and photodiodes for near-infrared spectroscopy (Christoph, et al. 2013). Lilypad Arduino (Buechley, 20018 and Stern, 2008) developed by MIT researchers is a microcontroller that can be easily embroidered or integrated with fabrics, connected to sensors, actuators and Arduino coded for multiple functions (Figure 2.26). Based on state of the art research review, traditionally crafted products could be intervened and embedded with smart technology for augmented functions to aid users in daily life and in several domains, such as health, geriatric, to meet the needs of the specially-abled, military, home interiors, automobile, etc. in a more Indian context. This would not only preserve hierarchical

traditions but also provide a cutting edge to traditionally crafted products and educate groups of artisans to create technologically competent designs with value addition.

Figure 2.24: Woven smart fabric; **Figure 2.25:** Woven sensors, University of Laval; **Figure 2.26:** Lilypad Arduino embroidered on fabric

Developments in smart textiles as discussed above indicate that the future of textile is going to more than just clothing the body, existing functionalities (waterproofing, weatherproofing, fireproofing, etc.) and being a stationary artefact. Textile wearables will be able to *sense, react* and *adapt* according to user needs, and this is why researchers need to identify suitable augmentation of varied textile crafts of India to retain the cultural and traditional essence and yet bring them at par with the technological advancements. Available technology such as sensors (light, temperature, colour, proximity, etc.), LEDs, RFID, NFC tags, electroluminescent wires, photochromic ink, thermo-chromic ink, conductive ink, conductive thread, flexinol wires, Lilypad arduino, etc. provide immense potential to explore and integrate these elements into existing design elements of the textile crafts to augment their functionality and become an active part of Internet of Things. Figure 2.27 discusses few gaps that could be addressed through research on interactive textiles and traditional textiles of India.

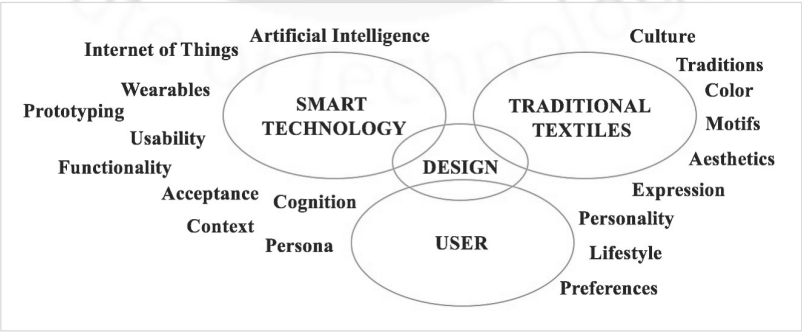


Figure 2.27: Design implications for smart textile crafts

It is important to understand here that the method of craft making need not be modified entirely when electronic elements are being integrated. It is selective replacement of

traditional embellishments for example – mirrors with LED, Lilypad Arduino circuit neatly embroidered in *zardozi* pattern to complete a circuit, conductive thread used as weft or warp yarn or used for embroidery, etc. This requires considerable understanding of how to work with electronics at an elementary level. The role of designer studios and NGOs could become important, as they can contribute in initial development of small samples with considerable quality. Also, not all craft practices need to be transformed to become smart, but authors posit that only few textile crafts could be augmented or produced as custom samples for specific user applications. These could be advertised and marketed as unique/limited collections as part of the brand portfolio.

Figure 2.28: *Pabuji ki phad*; **Figure 2.29:** *Banjara* woman in traditional attire; **Figure 2.30:** *Kanjeevaram* saree [Untitled illustration of Phad; Banjara woman; and Kanjeevaram saree]

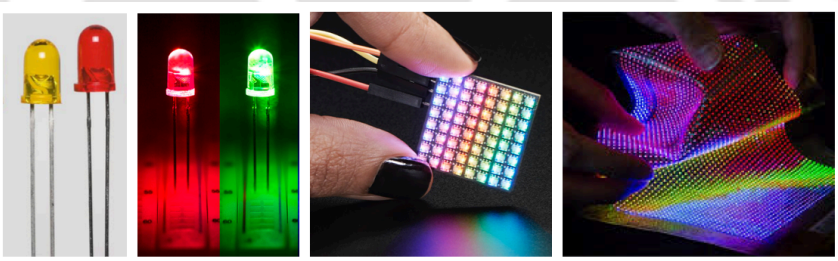


Figure 2.31: Conventional LEDs; **Figure 2.32:** Micro LED chip; **Figure 2.33:** Luminous LED textile [Untitled illustration of Conventional LEDs; Micro LED chip; and, Luminous LED textile]

To cite a concept, holography and digital technology could be employed to ancient storytelling crafts, such as *Pabuji ki phad* (Figure 2.28) and others (*Mata ni pachedi*, *Jadopatia* storytelling) to not only design a contemporary version but to also retain the traditional value, essence, skill of crafting and storytelling in a new format that could last for years to come. Similarly, other crafts of hand embroidery (Figure 2.29 – *Banjara* embroidery) or weaving (Figure 2.30 – *Kanjeevaram*) could be embedded with electronics for bio-monitoring, emotion sensing to change appearance, tactile or sound effects for protection, to facilitate subtle communication between two known/ unknown individuals within the same space, to wirelessly monitor the positioning of an object/ user, to control

the environment or behaviour around the textile or even to act as information repository of that particular craft making in detail. The textiles could be embedded with a NFC tag (Near Field Communication), that can be scanned by an external device (such as a cell phone, etc.) which could direct the user to an online information repository about that particular textile craft, its history, motif vocabulary, craft making, craftsmen, branding and advertising. However, for the information repository, it will be important to verify the data being provided, necessitating a regulatory authority. It is important to design the smart applications for a specific scenario, prototype, test on users and further iterate. It would also be important to give the user complete command of personal information being transmitted with privacy and control. Figures 2.31-2.33 depicts the advancements in LEDs over a decade that could have implications in the digital crafts development.

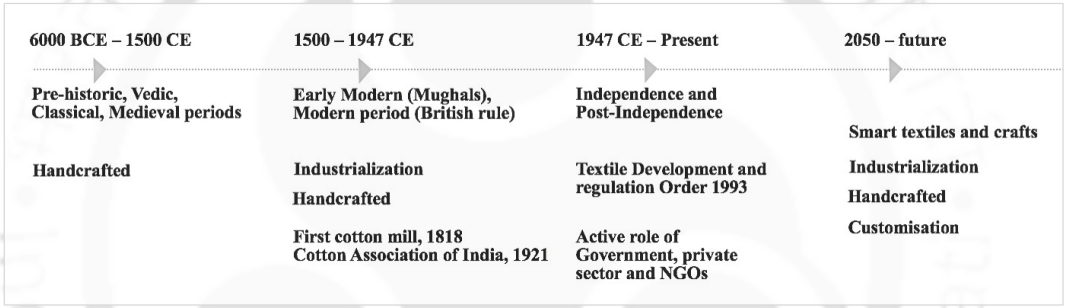


Figure 2.34: Timeline for textiles in India (Deepshikha, et al., 2017)

The authors have thus categorised the history of textiles in India into four phases (Figure 2.34) – Phase 1 – which begins from pre-historic till the Medieval kingdoms, where handwoven and hand-worked fabrics were created. Phase 2 – comprises of Mughal patronage to arts and crafts, and the British Rule. Industrialisation that led to establishment of over 400 textile mills in the country was an important development during this phase. However handwoven and hand-worked textiles were still being produced. The historical data has been studied from Kax Wilson, History of textiles, 1979. Phase 3 - Post Independence government took active role in setting up a Ministry for textiles, several funding schemes, upgradation programmes, etc. to upscale both the handloom and power-loom sector. Several brands (private and public sector) and NGOs also came up during this phase. The authors forecast the future of the textile scenario in India, in the fourth phase where handlooms, handicraft and power-loom would still exist with an addition to manufacturing of smart textiles for context based applications. It is here where designers and craftsmen could merge together crafts with smart technology and push the envelope of textiles beyond clothing and protection to sensing, reacting and adapting with its

environment. Through experimentation and scientific studies, this would also bridge the gap between technology, research, textiles and craft sector in academic and industrial domains.

2.3 Literature study on traditional textiles of India – traditional, contemporary, trends

Textiles have been embedded with colours and motifs since prehistoric times to celebrate, protect or symbolize cultural beliefs (Bhatnagar, 2004; Bhatnagar, 2005; and, Ambalal, 1987). They have been largely inspired form flora, fauna, architectural forms and everyday things (Chisti, 2010; Gillow and Bernard, 2008; and, Katiyar, 2009). Storytelling has also been a part of textile crafts, where deities and other symbolic motifs represent a mythological story or local legends. Both the skills of craft making and the textiles have been passed from one generation to another to perpetuate the traditions. With globalisation, poor economic status of craftsmen and other reasons, the craft practices have been declining gradually (Ministry of Textiles, 2015). The textile heritage rich and varied in myriad forms needs to be preserved as an integral part of societal heirloom.

A recent publication by Veenu, Katare C. and Sharma R.B. (2016), reiterate that traditional textiles of India comprise motifs mostly inspired from architecture, flora, fauna and everyday things. For instance, auspicious symbols like *shankha* (conches*), kalasha, rudraksha* find reference in scriptures and mythology. Conch is possessed by several Hindu gods and goddesses and is blown for purity and prosperity. *Kalasha* is the water pitcher in which water is kept for ceremonial or everyday purposes. It is said to symbolize womb, fertility and new beginnings. Lotus is said to symbolize purity and auspiciousness and is offered as part of prayers. Lotus holds special significance in Buddhism and depictions in Ajanta cave paintings. The paisley design, *ambi, mangai* or *karrey*, is used in different regions of the country with different names and significance. The motif was initially introduced to India by the Mughals as an integral element of textiles through Persian influence in design and architecture. *Mangai,* as called in Tamil Nadu, is inspired from mango fruit and has its roots in Hindu mythology. Parrots have been denoted as birds symbolizing courtship and passionate love. Fish is considered to be a reincarnation of Lord Vishnu, one of the trinity gods in Hinduism, thus considered holy. The elephant is the carrier of the Hindu Lord Indra and symbolizes wisdom, royalty and strength. It finds mention in mythological war scenes and also in Buddhism. Few images below depict popular motifs of traditional textiles of India (Figures 2.35-2.38) – *Benarasi* (*Konia* –

mango motif), *Patola* (Tiger, Elephant), *Bandhej* (*Kalasha*, Elephant), and *Paithani* (*Ashavali* lotus, Peacock)

Figures 2.35-2.38: (Left to right) *Benarasi, Patola, Bandhej, Paithani* [Untitled illustration of *Benarasi* motif; *Patola; Bandhej*; and, *Paithani*]

Figure 2.39 (L-R): Elephant- Brocade, Block print, *Pipli, Bandhani* [Untitled illustration of Elephant motif brocade; block print; *Pipli*; and, *Bandhani*]

Some of the common motifs include fishes, elephants, horses, tigers, parrots, peacocks, creepers, vines, tree of life, *kairi* (mango motif), *rudraksha* (beads), flowers – jasmine, lotus, *kalasha* (water pitcher), palanquins, chariots, etc. Each of these motifs have significance, which could be spiritual, religious, occasion specific - meant to bring good luck and fortune to the wearer, associated with royalty, authority and so on (Bhatnagar, 2004; Bhatnagar, 2005; and, Veenu, et al., 2016). The textiles of India could be broadly divided into woven, printed, embroidered and resist dyed (CBSE, 2014). Depending upon the type of textile technique, the same motifs appear differently creating specific vocabulary for the textile of that region. Figure plate 2.39 depicts *Elephant* motif in *Kanjeevaram* brocade woven silk from Tamil Nadu located in the south of India, Block printed cotton fabric from Gujarat in the West, *Pipli* applique work from Orissa in the East and *Bandhani* tie-dyed fabric from Rajasthan in the West. The same motifs differ in shape owing to the crafting technique being used. In another example, the *lotus* motif is depicted in hand embroidered *Kantha*, brocade woven *Paithani* and *Benarasi sarees* and hand-painted *Kalamkari* fabric in Figure plate 2.40.

Figure 2.40 (L-R): Lotus motif- *Kantha, Paithani, Kalamkari* and *Benarasi* brocade [Untitled illustration of Lotus motif *Kantha; Paithani; Kalamkari*; and, Brocade]

The motifs are largely drawn from nature – flora and fauna and local architectural styles. As depicted in Figure 2.41, temple border brocades are woven in *Kanjeevaram* silk in South India as they are inspired from massive temple architectural styles. Peacocks and mythical birds are also derived from mythological carvings of temple friezes apart from local flora as depicted in the woven brocade border (Figure plate 2.41).

Figure 2.41 (L-R): Temple border woven brocade, South Indian temple structure; and Peacock brocade and mythical birds carved on a temple frieze [Untitled illustration of temple border; South Indian Temple; Peacock brocade; and, carved frieze]

Traditional textile motifs have mythological, religious, festive, occasion-specific, occupational or contextual significance (Veenu, et al., 2016; Chisti, 2010; and, Katiyar, 2009), for example – *Peacock* is a *vahana* (vehicle) of mythological Goddess *Saraswati*, it finds prominence in Lord *Krishna's raas leelas* (leisure dance forms) and represents love, fertility, beauty, immortality, courtship and divinity. *Parrots* are vehicle of God *Kamdeva* and Goddess *Rati* symbolic of love, courtship, passion and are widely used on bridal sarees. *Elephant* represents strength, prosperity, royalty and authority. *Lotus* is of divine significance and represents purity, prosperity, intellectuality, peace and cosmic harmony. *Creepers* though Persian in origin, have also been used with mythological representations signifying growth, harmony and prosperity for present and next generations.

The colors are also used symbolically (Sharma, 2017), for example – *Red* and *Maroon* represent passion, love, fertility as worn for *auspiciousness* by brides and newly-weds and as *authoritative* for royalty. *Yellow* represents the Sun, enlightenment, divinity and is worn for festive and auspicious occasions. *Green* represents growth, prosperity, abundance and fertility. *Blue* represents skies and seas, representing vastness, intellectuality, infinity and is mythological in nature representing Gods, such *as Vishnu, Rama* and *Krishna*. White although represents abundance, mysticism and intuition on one hand, is regarded to be sorrowful and devoid of pleasure, desires or attachment, on the other.

At present although motifs and colors do symbolize ancient beliefs, ethos and traditions, they are worn by people irrespective of caste, religion or status. With cross-cultural influences on clothing and preferences and merging of traditions, various kinds of textiles are worn and preferred by the modern consumers from different cultural backgrounds and ethnicities.

2.3.1 Contemporary trends – Fashion in India

As mentioned earlier, the textile industry in India contributes 4% to GDP and 14% to industrial production while the size of India's textile market was 137 billion in 2016 (IBEF, 2018). The fashion industry share presently is 68 billion dollars (Fashionunited, 2017). Wanamaker Department Store in Philadelphia in 1910 and Selfridges in London in 1930s witnessed the first fashion shows (McInnes, 2011). It was only 20 years back fashion shows started in India. Due to the large young population of the country, the Fashion Industry in India is expected to reach US$ 400 million in a couple of years (Dalal, n.d.). Globally, Fashion designers create two collections in a year, Spring-Summer and Autumn-Winter. The collections are showcased at fashion shows where buyers place orders and the press media helps in propagation. Some designers have taken to performance and installation art to showcase their products (McInnes, 2011).

There were handful of famous designers from India in the 1980s, however with economic liberalization in 1990s, the fashion industry experienced a boom. India's strength lies in the varied traditions, its production capacity – largest for cotton (The Cotton Corporation of India, 2015), the second largest producer for silk (International Sericulture Commission, 2013), skilled workforce and the fusion of western influences over time (Kanwar, n.d.). The luxury retail sector of India is expected to reach 700 billion dollars from the present 400-billion-dollar market as per Northbridge Capital. Ritu Kumar, Rohit Bal, Tarun Tahiliani, Ritu Beri, Manish Malhotra, Sabyasachi, Satya Paul, Raghavendra Rathore are

few pioneers of the mainstream fashion industry. Lakme, Wills Lifestyle and other Fashion weeks have provided immense opportunities for new designers to showcase their collections and establish brand houses. These designers have taken the traditional craft-form and new style lines to the ramp. Several fashion brands like Fab India, India Circus, Tvach, Anokhi, Bhu:Sattva, Ethicus, Manyavar, Peter England, Allen Solly, Monte Carlo, Provogue, Louis Philippe, Flying Machine, AND designs that have shown exquisite quality products that match Indian and International standards. Few of these brands work exclusively to upscale and modernize the traditional textiles to a global level, retaining the essence and supporting the craft communities. Figure 2.42-2.43 depict few contemporary traditional textile clothing. These brands indicate optimistic growth for traditional crafts and textiles in contrast to fact that technology has led to rapid decline in crafts.

Figure 2.42: Designed by Ritu Kumar (Sangharajka, 2014).; **Figure 2.43:** Tarun Tahiliani (Mehta, n.d.)

Designer Prerna Florence Isaac in her boutique Rangoli Auroshilpam in Auroville, Pondicherry (in Southern India) creates new style lines with an indo-western fashion. Pallu of sarees are used for tops while, remaining part of the saree for creative outfits. By creating trendy dresses, Rangoli not only promotes handicrafts of India globally but also supports communities from where the fabrics are sourced and communities near Pondicherry. It has played immense role in supporting the Benarasi weaver community and rehabilitating villages around Pondicherry after tsunami struck in 2004. Similarly, Ethicus, an in-house brand of Appachi based in Pollachi, Tamil Nadu (in Southern India) creates unique hand crafted products and links handicrafts with ethical fashion. It has also obtained the GOTS, Global Organic Textile Standard and Organic Blend content standard certifications. Several such brands and designers have taken handloom and handcrafted products made in remote villages of the country in International Fashion Shows and Exhibitions.

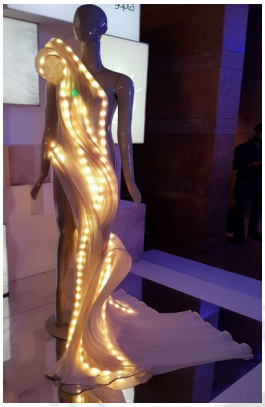
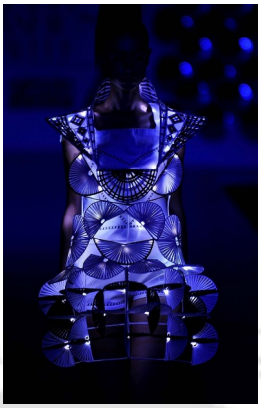




Figure 2.44: Gaurav Gupta IBM LED Saree gown 2017; **Figure 2.45:** Pankaj and Nidhi *Geometrica* 2012; **Figure 2.46:** Leconaet and Hemant, 2013

Designers need essential understanding of consumer culture, user needs, usability, manufacturing involved and fashion while embedding interactive technologies in textiles. Significant experimentation has been conducted for health, fitness, bio-monitoring, active sports and military preparedness. However, a certain gap exists for designers to understand the optimum microclimate, aesthetic, technical and cultural needs of the target market to utilize the potential fully. Thus, design research for wearables needs to be taken beyond merely studying human biology, electronics, multimedia, fashion, textile technology and marketing (McCann, et al., 2005).

LED Fashion have been explored limitedly in case of the Indian textile and craft industry. Designer Gaurav Gupta for Vogue Women of the Year Awards 2017 created a LED saree gown with IBM that could change colours to express personality traits (Singhania, 2017). Designer duo Pankaj and Nidhi showcased glowing geometric LED dresses as part of a series of garments of Collection Geometrica (Pankaj and Nidhi, 2012) at the Wills Lifestyle India Fashion Week for Spring Summer 2012 (Figures 2.44, 2.45). Figure 2.46 depicts LED Dress by Leconaet and Hemant *Luminocity* showcased at Bonjour India 2013 (Mistry, 2013). However, huge potential lies in merging elaborate crafting traditions of India with smart materials as has been explored as part of the present research. The authors intend to explore the role of the motifs, how digitisation is likely to impact and what could be the possible applications through Semantic Analysis. The authors intend to explore the role of the motifs, colors and other design elements in influencing moods, emotions, personality and preferences through user experience studies that could help in creating design heuristics. The authors intend to identify few textile elements for wearable prototyping in subsequent stages. The authors do not aim at comprehensive documentation of various

textile crafts of the country but to identify relevant textile elements that could be worked upon for Semantic Analysis and Wearable prototype development in the subsequent stages, which will be elaborated in Chapter 4 while designing prototypes.

The Literature study being conducted on traditional crafts is to fulfil an objective of the authors being able to derive design elements from existing crafts and explore the scope of technological intervention and possibilities of expression of emotions, feelings, comfort levels, etc. through experimentation. Significant literature is available by notable authors on various crafts of India, the novelty would be in the idea of exploration of technological intervention and understanding the scope of such applications through present research.

2.4 Literature study on design semantics

Design Semantics (Figure 2.47) aims at studying the significance of signs and symbols and their associated meanings in linguistic and visuals. *Semiotics* by Daniel Chandler was referred to, to understand linguist principles of Saussurean and Piercean

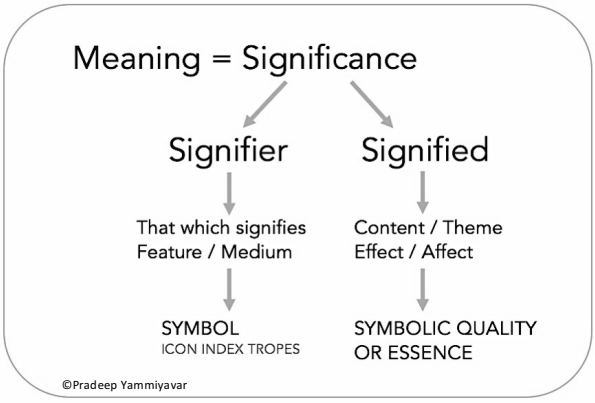


Figure 2.47: Design semantics

traditions, Symbol-Icon-Indexical signs, Arbitrariness, Types and Tokens, Syntagmatic and Paradigmatic axes, Semiotic Square, Spatial and Sequential Relations, Structural Reduction, Tropes, Metaphor, Metonymy, Synecdoche, Irony, Denotative and Connotative meanings and Myths. This science which emerged from linguistic discipline has been used by designers for analysing product and visuals. However, the authors intend to evaluate the role of textile crafts in indirect communication using Semantic Analysis, not sufficient published literature was found in this regard in India or elsewhere. Section 4.4.2 presents a semantic analysis of static and dynamic digital crafts based on learnings from Figure 2.47.

2.5 Literature study on User Experience Design

Although cognitive psychology as part of User Experience Design is a vast domain, our literature study focusses on the keywords – moods, emotions, personality, preferences, opinion, user behavior for socialization – related to textiles particularly which could contribute in designing textile craft wearables. Researchers have occasionally attempted to enquire whether textiles have greater potential than other material in embodying individual emotions due to their closeness to the skin as well as providing collective experiences (Dolan, 2015; and, Dolan and Holloway, 2016). In Europe, garments worn for christening and wedding provide a wide range of emotions for constructing emotional vocabularies. Not only does the wearer emote differently upon wearing the garment but the maker and the entire process of crafting the garment creates a range of emotions corresponding to the activities involved. For example, elaborate embroideries on curtains, bed sheets, knitting in western or European countries is a celebrated tradition that emphasizes power of maternal love and female sociability. It helps to preserve family memories, craft techniques and promote community living and sharing ethos when done as a group activity. Some crafts possess religious properties embedded in them which retains the sanctity of the family or community traditions. For instance, using red clothes for infants in Denmark marks protection form evil or *Pichwaii*, painted and printed textile, embeds various spiritual and ritualistic aspects of textiles. *Phulkari*, an embroidery from Punjab (in Northern India), begins when a daughter is born. The grandmother starts embroidering a shawl to be gifted on the wedding day. Dollan and Holloway (2016) mention that textile embroideries between 17th and 19th centuries in Europe were meant for domestic rather than commercial production thus engraving deeper emotions as the commercially produced fabric did not retain the same values as the hand-crafted ones.

Researchers from Manchester University have used quantitative analysis to inquire casual relationships between emotions, moods, clothing style, preference and personality factors. Linear regression analysis stated that mood, personality and clothing were strongly related, mood influenced preference significantly while personality influenced moderately (Moody, et al., 2009). Emotions, Feelings and Moods are terms related to human subjectivity that cannot be easily observed, quantified or verified (Wiebe, 1990). In addition, due to lack of scientific or specific definition and differentiation between these terms it is difficult to identify how they are related to each other.

As described by Dolan (2015), emotions have three characteristics from the psychological perspective – they are experienced by the entire body instead as mental events alone;

emotions are difficult to control unlike cognition; and emotions have greater overall impact on our behaviour than thoughts. Kleinginna and Kleinginna (1981) suggested a formal definition of *emotion* as a complex set of interactions among objective and subjective factors mediated by hormonal and neural systems, that result in following: (i) give rise to feelings of pleasure, displeasure or arousal, termed as *affective experiences*; (ii) generate cognitive processes such as *appraisals, labelling processes* or *emotionally relevant perceptual effect*; (iii) active widespread *physiological adjustments* to the *arousing conditions*; and (iv) lead to *behaviour* that could be *goal-directed and adaptive*, not always expressive.

Unlike emotions which have a stimulus, the cause of moods may not be easily identifiable. For instance, a person may get up in a happy or sluggish mood, but it is difficult to identify what created that mood (Morris, 1992). Anxiety or depression may stretch over a time period of months to years. Hence mood has been described as affective state as a result of nothing specific or everything (Frijda, 1986). Visceral, behavioural and reflective aspects incorporate emotions and cognition for any successful design. When colour monitors were introduced, few had difficulty in adjusting to the change from black and white. There was not scientific justification why colour monitors were being sold highly as personal computers; but it did indicate that colour was justifying some (aesthetic) needs that had to be unfurled in 1980s (Norman, 2003).

Mahlke and Thuring (2007) utilise EDA (Electrodermal activity), EMG (electro-myographic responses) and SAM (Self-Assessment Manikin). Both subjective and physiological measurements have pros and cons in terms of accuracy. Physiological measurement has not been a part of experiments conducted in present research. Digital crafts and their effect on emotions and moods, research being in nascent stage in context of India, subjective measurements have been considered before physiological measurements can be undertaken in future, to be able to design experiments.

Emotions play an important role in creating opinions about products or things being *good, bad, nice, not nice, dangerous, comfortable*, etc. – a constant judgement that drives our thinking and behaviour and often influence *moods* as described in the following image (Figure 2.48). Munezero, et al., 2013 describe the various stages of opinion formation, the conscious and pre-conscious stages are debatable indeed. Also, the sequence of opinion formation may also differ from context to context. The authors of the thesis focus on the *Affect* of User Experience while interacting with a product or prototype and have employed subjective measurement scales for emotions and feelings that could represent their preferences through visual cues of the prototype scarves and jackets designed.

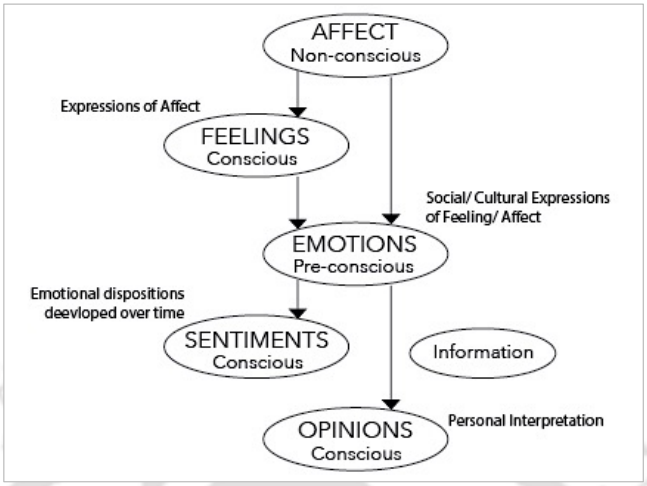


Figure 2.48: Image describing Affect, Feelings, Emotions, Sentiments and Opinion (Munezero, et al., 2013)

A study by Jiang and Liu (2009) revealed that the color of clothes plays significant role in emotional expression, psychological suggestion and image building and can also greatly influence apparel sales. The American Psychological Association (2017) describes personality traits as characteristic differences between patterns of thinking, feeling and doing which differs from one individual to another. Recognition and interpretation of information received through sensory stimuli could be called as perception and this may or may not lead to action due to inhibition (Dikksterhuis and Bargh, 2001). Researchers define moods and emotions as following (Pathak, et al., 2011) - Feeling "A positive or negative reaction to some experience" or "The subjective experience of emotion". "Emotion" is a stirred-up state due to physiological changes which occurs as a response to some event and which tends to maintain or abolish the causative event". "Affects are waves of emotion in which there is a sudden exacerbation of emotion usually as a response to some event". Mood is "the emotional state prevailing at any given time" or "The dominant hedonic tone of the moment."

Verbrugge M. L. (1997) mentions that according to proximity principle, similar people are likely to become friends where friendship is source to social contact, assistance and intimacy. However not much is known as to how friends are chosen, how large can heterogeneous groups be and what information is exchanged. Study conducted at the University of Michigan reveals that homogeneity based on social status, attitude, interests, intelligence and personality traits may be significant in establishing friendship (Verbrugge,

1997). Feelings play an important role in creating opinions, which lead to a particular behavior and judgment that users are constantly engaged in (Munezero, et al., 2013).
Users are specific in terms of how they communicate and express themselves in a social space. Similarity in traits, attitude, behavior govern individuals likes and dislikes and how social groups are formed (Heather, 2013; and, David, et al., 2011). Proximity principle mentions how individuals build relationships through sharing beliefs, experiences and social exchange (Heather, 2013; and, David, et al., 2011). If textiles could enhance social facility, social cognition and synchronicity (Goleman, 2006) with known and unknown individuals around non-verbally, this could lead to collective intelligence. The intention of authors is to understand user behavior in social space and relevance of textiles in augmentation of self-expression which will be elaborated in further sections through design and experimentation.

2.6 Literature study on craft research

The studies are more qualitative in nature and qualitative assessment of designs was learnt that could be incorporated in present research. Elizabeth Bye (2010) stresses on issues in clothing and textile design research, the need for merging craft and design research in present times. Kokko and Dillon (2011) report a qualitative assessment and detailed research methodology for evaluation of artefacts as expression of cultural heritage. The assessment has been carried out on college students from different countries, their perceptions and understanding about crafts from respective cultures in detail. Nimkulart N. (2012) presents a unique method of crafting contemporary clothing based on traditional skills and qualitative assessment along with research methodology in detail for fashion and craft practitioners and researchers.

2.7 Identifying gaps for research in context of India and its implications on the design process and experiment design

The literature study illustrates how technological advancements have been taking place globally in the sector of textiles and it sets examples for how seamlessly this could be imbibed into selected traditionally crafted textile products to retain the essence and yet enhance user needs when applied to specific applications. Although with advent of industrialisation the craft practices have suffered competition, embedding intelligence may bring them at par with contemporary wearable design in a niche segment. The authors posit

that the examples discussed in sub-section 2.2.3 could be explored with traditional designs of India thus reviving the cultural motifs and also imparting a new meaning to the smart textile craft apart from a suitable user specific application.

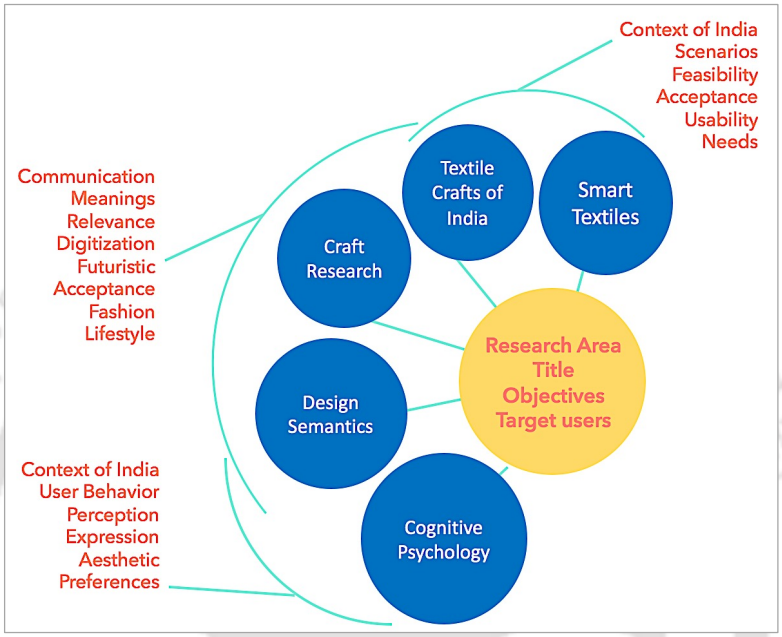


Figure 2.49: Gaps identified during State of the Art Literature study

The present research focusses on how merging the western developments and designs into the context of traditional Indian crafts could strengthen the role of traditional crafts in the emerging Internet of Things and also retaining the essence of hierarchical crafts. The authors infer that the potential for traditional practices in textile crafts to absorb technology and evolve into smart textiles is more on the optimistic side. As described in Figure 2.34, keeping pace with how the textile were crafted centuries ago and how designers have been promoting craft products contemporarily, it is now where designers and researchers could integrate technology in textile crafts and design the next generation smart products for the future deeply rooted within the hierarchical crafts traditions of the country. Figure 2.49 depicts the gaps identified that correspond to the main research questions being addressed in this thesis in Table 2.1.

From Table 2.1, Exploratory Study 1 intends to understand the perception of young users towards personality traits, opinions, moods-emotions evoked in them on the basis of a photo-elicitation study. While, Exploratory Study 2, intends to understand the levels of boundaries, emotions, feelings, comfort levels that users experience in certain social contexts. On the basis of the findings of these exploratory studies, prototypes will be

designed as explorations of textile craft traditions and embedded electronics. Further, these digital crafts will be experimented with young participants for emotions evoked in them, expression of feelings and non-verbal expression in their social space along with usability assessment and understanding the levels of technology acceptance through questionnaire based rating scales which will be statistically analysed. The table with research questions will be discussed again where hypotheses is being formulated to show the connections between them (Section 4.5).

Table 2.1: Gaps identified through literature study corresponding to research questions

	Gaps identified from literature study	**Corresponding research questions**	**Research Flow**
1	Study on preferences, personality, emotions evoked, opinion and perceptions with respect to traditional textiles of India did not seem evident.	How do traditional textiles influence and evoke emotions, opinion, judgement and personality traits among young users?	Exploratory Study 1
2	Textile wearables with respect to usage in context of India – usability assessment and acceptance studies were not evident in published sources	What are behavioural aspects of users that could influence designing of textile wearables?	Exploratory Study 2
3	Exploring integration of textile craft heritage of India with smart materials owing to advancements in e-textiles was limited.	What are the ways in which smart materials could be seamlessly embedded with traditional textiles for augmenting functions targeted at young users?	Designing digitally crafted wearables
4	Study on textile wearables capable of non-verbal expression in context of Indian scenario or with Indian users was limited.	Are there possibilities of enhancing self-expression and non-verbal communication through digital textiles in the social space, if so how can they be captured and quantified?	Preliminary Experimental Study and Experimental Study 1 and 2

Chapter Summary: *This chapter discusses literature and state of art studied in the sub-domains of interactive textiles, traditional textiles of India, Design semantics, Cognitive psychology as part of User Experience Design pertaining to textiles, personality, moods, emotions and preferences and craft research. The gaps identified and corresponding research questions have been formulated which lead to corresponding exploratory and experimental studies, the methodology followed will be reported in the next chapter.*

Chapter 3

Research Methodology

This chapter explains the methodology adopted for conducting present research which comprises two exploratory studies and three experimental studies. The experimental set up, procedure, tools used, sample size and methods of analysis have been reported.

3.1 Introduction

The previous chapter reviewed few sub-domains of literature studied which led to identification of need and gaps to be addressed in the present research. Based on this, our objective was first to understand users, then design digital craft prototypes based out of traditional textile crafting skills of India and further evaluate the prototypes with users. To explore and answer the research questions, a qualitative and quantitative exploratory and experimental research methodology was adopted. User centeric design process was applied while designing prototypes which became tools for experimental evaluation. In continuation of Figure 1.3, Figure 3.1 elaborates the two exploratory studies conducted to understand user perceptions and behavior and the two experimental studies conducted for evaluation of digital crafts for non-verbal self-expression in social space of users. The research comprises – (i) Understanding the state of the art, research potential and the young users of India through the Exploratory studies; (ii) Designing of digital craft prototypes on the basis of studies conducted and literature analysed; and, (iii) Experimentation of non-verbal expression through the prototypes with young Indian users in a social context.

The literature study led to understanding of the scope of the research area, need and feasibility of prototyping and methods of evaluation. It was found that few researchers in India had studied the relation of traditional textiles and user experience, i.e. role of emotions, moods, feelings in perception, preferences, expression and the capacity of textiles to evoke experiential process. Hence the thesis focusses on understanding few aspects of emotions and feelings pertaining to traditional textiles and then with respect to digital crafts.

Exploratory study 1 tries to capture the capacity of traditional textiles (the motifs, colors, and look of the textile) to evoke, moods emotions and feelings in the viewers through a photo elicitation study. While exploratory study 2 tries to understand the importance and levels of emotions and feelings users experience in listed social contexts and the kind of

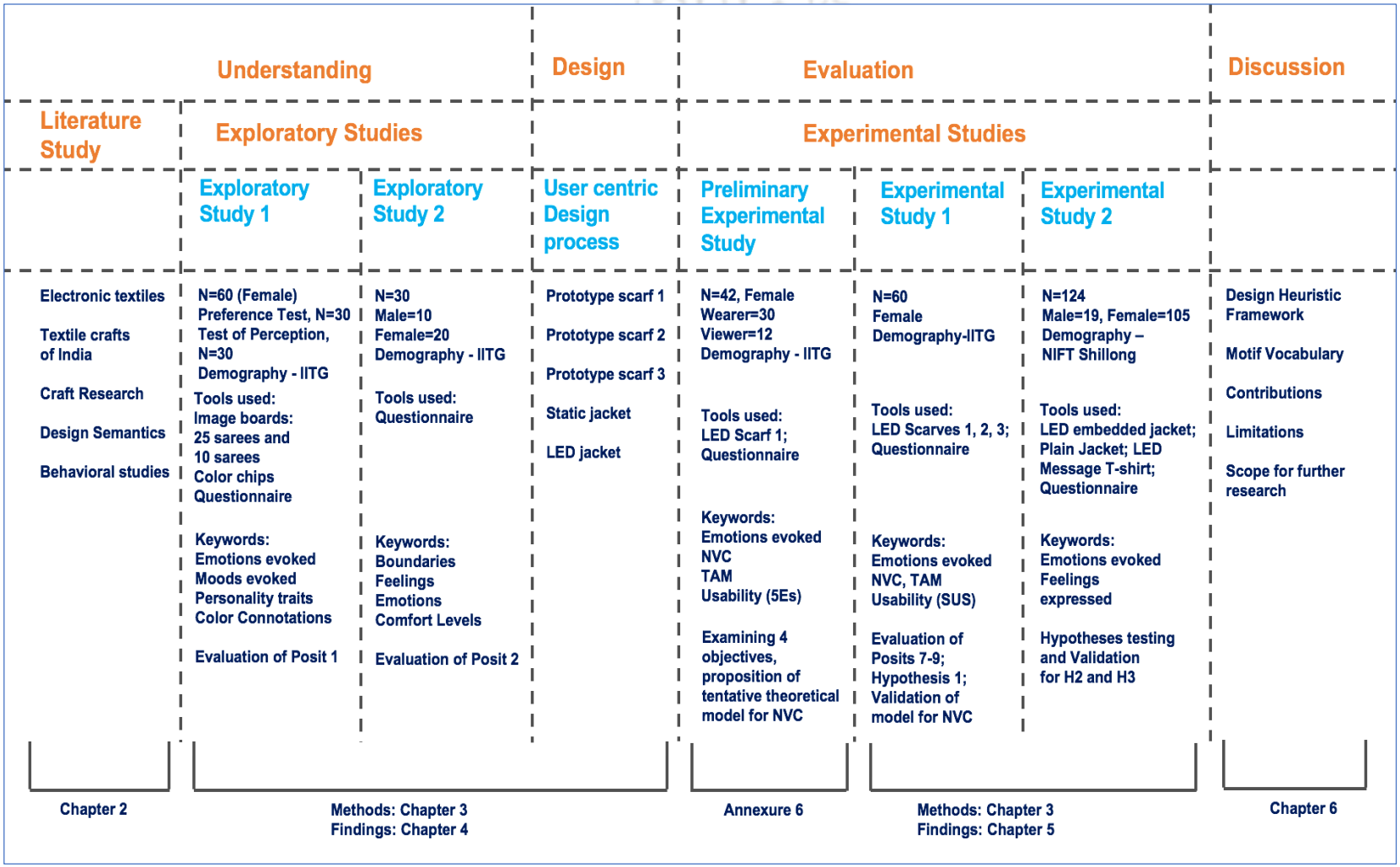


Figure 3.1: Research Experiment Design

boundaries and comfort levels that need to be communicated. The respondents were asked if they believed that textiles could facilitate in expression of these above-mentioned attributes – emotions, feelings, comfort levels and boundaries. With a positive response generated and related literature studied, Design exploration of digital crafts was undertaken. Following which 3 experimental studies were conducted to understand the role of digital crafts in non-verbal self-expression in the social space of users – to understand emotions evoked, feelings expressed, capacity to communicate social intelligence, the usability aspects while interacting with prototypes and level of acceptance for the digital crafts (Technology Acceptance Model). Preliminary Experimental study has been reported in Annexure 6 and Experimental studies 1 and 2 have been reported in Chapter 5.

To summarize few sources of scales adopted in the studies: The Exploratory Study 1 on sarees utilizes a Likert scale for measuring emotions, adopted from literature studied in Kansei engineering (Jeong and Lee, 2006; Pitaktiratham, et al, 2012) and similar papers. Other questions on moods, colors, motifs were asked to create a foundation for subsequent stages. The emotions were derived from Plutchik's wheel as most relevant set of positive and negative emotions by the authors after consulting experts. The first study being exploratory in nature, a photo elicitation method (Richard, et al., 2015) was used to understand the responses, as using actual textile samples would generate several other attributes such as – drape, lighting, texture to be considered. The Exploratory Study 2, was focused on understanding young Indian population, their preferences, emotions, feelings, comfort levels and boundaries in social contexts. Although studies were conducted on proxemics (Sheppard, 1996), psychology for socialisation (David, et al 2011, Verbrugge 1997), but the questions asked were exploratory in nature, as limited literature was available in Indian context of socialisation and scientific studies conducted. Hence to generate response to the keyword in question, factorial design matrix were generated keeping in focus their relevance for further stages of design explorations. After the exploratory studies were conducted, the three experimental studies had Likert scale for measuring *emotions* and *feelings* (Jeong and Lee, 2006; Pitaktiratham, et al, 2012, Plutchick 2001), aesthetics (Blijlevens, et al., 2017), Usability (System Usability Scale, 2018; Quesenbury, 20014), and Technology Acceptance (Davis, 1989) were adopted. From Daniel Goleman 2006, new scale of measurement for NVC was designed and validated for future research which will be discussed subsequently.

In this chapter the demography, sample size, experiment design, experiment set-up, tools used and experimental procedure followed along with statistical and qualitative methods of analysis used will be reported for each of the four studies of Figure 3.1. The studies were

conducted to test posits and validate model for non-verbal communication using digital crafts (Figure 5.3-5.5) and test the three hypotheses mentioned in Chapter 5 (5.2.1, 5.3.1 and 5.3.2).

3.2 Exploratory Study 1

The first Exploratory study was a photo elicitation (Richard, et al., 2015) based cultural probe which aims at deriving insights regarding the traditional wear trends of women of age 18-28 years. The images used have been chosen by the same age group as most preferred while denoting preferences. The study gathers information about emotions generated in respondents upon viewing a set traditional sarees, their colors and patterns. The study also reports the characteristics that drive the respondents' opinions with respect to traditional wear. And whether dresses are worn to make a statement or it is a random choice. Information collected from around 30 respondents provides key insights about preferences of women for handloom and handcrafted sarees.

3.2.1 Participants and sample size for Exploratory Study 1

This study was conducted in two parts with 60 female respondents between the age group 18-28 years (30 respondents each participated for two tests; Table 3.1). These respondents study in a national technical institution situated in the North East of India. 56% of respondents belonged to East of the country while remaining 44% belonged to different parts of the country. 60% of them prefer traditional attire more than 40% who prefer western and other styles of clothing over traditional ones. Mean age of participants = 23.2 years and Standard Deviation = 3.46 years.

Table 3.1: Demography for Exploratory Study 1

Sample Size (Numbers)	**Age**	**Place of origin (Numbers)**	**Educational background**	**Marital status (Numbers)**
Test 1=30 Test 2=30	18-28 (years)	Semi-urban (34), Urban (26)	Under-graduates and Post-Graduates	Unmarried (54), Married (6)

3.2.2 Experimental Design for Exploratory Study 1

The experiment was conducted in two parts: first Group A of 30 participants had to choose five most preferred sarees of the 25 on the Image board (Figure 3.2). The selected

12 sarees as a result, had to be rated by the second Group B of a different set of participants on a questionnaire provided. The variables for the second part of the study have been mentioned in Table 3.1. The independent variables were the 12 sarees and 12 Colors (Red, Blue, Yellow, Green, Purple, Black, White, Gold and Silver). The dependent variables were 10 Emotions (Interest, Serenity, Joy, Awe, Amazement, Admiration, Boredom, Annoyance, Sadness and Apprehension); 10 Moods (Good, Bad, Lazy, Cheerful, Depressed, Adventurous, Ease, Rejuvenated, Enjoyment and Satisfaction). Qualitative content analysis was used which will be reported in section 4.2. [Please see Annexure 1 for un-filled questionnaire, Annexure 2 for filled questionnaire and Annexure 3 for Image board]. Reponses were also written in 2-3 words in tabular formats for corresponding questions (Annexure 2, p. 119-120), word count, categorisation was used for content analysis.

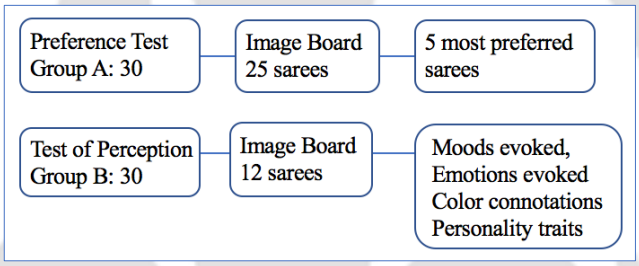


Figure 3.2: Experimental Design for Exploratory Study 1

3.2.3 Experimental Set-up for Exploratory Study 1

The tools used were – 25 saree image board (Figure 3.4); 12 saree Image board (Figure 3.5) and color swatches (Figure 3.6). The image board comprising of 25 saree images in rows of 5 in assorted placement pattern of different color, types and periods (1930's - contemporary). The sarees are different kinds of handloom woven products (*benarasi, ikat,* cotton, etc.) or hand-worked product (embroidered; saree 12). One is a half saree (saree 5), 2 are dhoti draped sarees (saree 9,12), while others are commonly draped saree styles. The 12-saree image board was derived out of top preferences of respondents out of the 25-saree image board. The 12 color families have been derived from the 12 sarees of the second image board. The experiment was conducted in an enclosed space with the tools and questionnaire kept on a table and the administrator and respondent seated adjacent or opposite to each other (Figure 3.3). The participants were briefed with the objectives of the experiment and after their consent the image boards and questionnaire was administered to them sequentially.

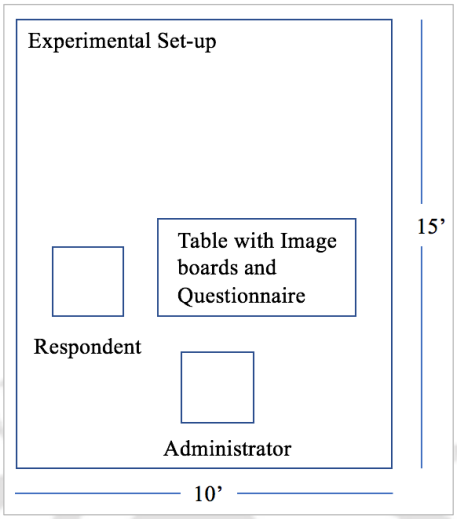


Figure 3.3: Experimental Set-up for conducting Exploratory Study 1

Figure 3.4: Tool 1 – 25 saree image board [Untitled Illustrations Sarees 1-25; Annexure 3];

Figure 3.5: Tool 2 – 12 saree image board; **Figure 3.6:** 12 color families – swatches

3.2.4 Experimental Procedure for Exploratory Study 1

In part one, 30 respondents were asked to choose 10 best sarees from a given tool (Image board of 25 sarees, Figure 3.4) on the basis of look, color, motifs, etc. similar to card sorting. The sarees of the image board were chosen from the internet from 1930s till present. They comprised different kinds of handwoven and hand worked sarees traditionally made in India, such as – *paithani, benarasi, zari embroidery, ikat*, etc. They

also encompassed 14 different draping styles. Since 3 sarees received similar counts, 12 sarees were chosen for phase 2 of the user study instead of 10 sarees (Tool - Figure 3.5).

In part 2, Respondents were asked to rank the emotions evoked in them on a Likert scale of 1 (least) to 7 (maximum). Five binary questions were asked. Descriptive questions included, defining 'mood', writing what colors mean to them and represent a list of moods with colors of their choice. The definitions for 'emotions' were provided from the google search knowledge graph. Respondents were asked multiple choice question for choosing most preferred motifs for a traditional saree for themselves. They rated emotions evoked by each of the 12 sarees on a seven point Likert scale. The 10 emotions derived from the Plutchik's Wheel (1980) were – *Interest, Serenity, Joy, Awe, Amazement, Admiration, Boredom, Annoyance, Sadness and Apprehension*. The emotions were derived from Plutchik's wheel as most relevant set of positive and negative emotions by the authors after discussion with researchers for a suitable set of attributes. Further they had to describe what each color meant to them in tabular format and also describe each of the 12 sarees as perceived by them in one or more words as an opinion of personality traits of the wearer. Figure 3.7 and 3.8 depict participants of the Exploratory study 1. The responses were made on the basis of look, color and motifs of the traditional textile images in the image board.

Figure 3.7: Administrator briefing participant; **Figure 3.8:** Respondents taking part in the study

3.2.5 Analysis of results for Exploratory Study 1

Qualitative content analysis and descriptive statistics were used for representing findings of Exploratory study 1 and analyzing Posit 1. Correlations between color, mood and saree was done by manual counting and tabulation. Emotions evoked by the 12 sarees

was represented graphically using MS Excel. Color connotations and Personality traits were categorized as positive and negative attributes and tabulated using word count.

3.3 Exploratory Study 2

This study aims at understanding how young people experience emotions and feelings in different contexts and levels of comfortability and boundaries for sharing information with different groups of individuals. This study is intended in contributing to designing of textile wearables in communicating emotions, feelings, comfortability and boundaries around users in their social space. So, although a larger study was conducted pertaining to socialization behavior of young respondents in different social contexts, data on *boundaries, emotions* and *comfort levels* have been reported as part of this thesis, as that has been utilized further in designing wearables for experimental evaluation.

3.3.1 Participants and sample size for Exploratory Study 2

The study was conducted with 30 young respondents studying in a national technical institution situated in the North East of India (Table 3.2). 60% belong to semi-urban and 40% belong to urban background. 20 female and 10 male undergraduate and post graduate level students took part in the study. Mean age of participants = 23.2 years and Standard Deviation = 3.55 years.

Table 3.2: Demography for Exploratory Study 2

Sample Size (Numbers)	Age (Years)	Male (Numbers)	Female (Nos.)	Educational background	Place of origin (Numbers)
30	18-28	10	20	Undergraduates and Post graduates	Semi-urban (18), Urban (12)

3.3.2 Experimental Design for Exploratory Study 2

For boundaries for sharing information with three categories of friends – 6 independent variables are – *Physical, Intellectual, Emotional, Material, Political and Sexual beliefs* and 3 dependent variables are *Strangers, Known friends and Intimate friend(s)*. For, Comfort levels experienced in sharing different types of information with different categories of friends – 6 independent variables are - *Stanger from different community, Stranger from same community, Acquaintances, Social friends, Close friends and Intimate friend*; while 5 dependent variables are types of information being shared

about – *Social, Academic, Professional, Relationships* and *Family*. For, Emotions experienced in different social contexts – 6 social contexts as independent variables are – *Office, School, College, Wedding, Park and Commuting (Bus, Train)*; and 12 dependent variables as emotions are – *Joy, Trust, Optimism, Love, Vigilance, Admiration, Surprise, Fear, Pensive, Remorse, Annoyance and Aggression*, from Plutchik's Wheel of Emotion (1980). Tables 3.3-3.5 depict the matrices as described above. The definitions for different kinds of friends/categories of individuals was given by the respondents themselves in a descriptive section prior to answering the tables 3.3-3.5. Types of Information shared with six different categories of friends was also presented in a tabular format for singular or multiple responses. Four binary and descriptive questions were also to be answered by the respondents. Annexure 4 depicts unfilled questionnaire and Annexure 5 depicts filled questionnaire used in this study.

Table 3.3: List of factors and variables for boundaries

Type of friend/people	**Physical beliefs**	**Intellectual beliefs**	**Emotional beliefs**	**Material beliefs**	**Political beliefs**	**Sexual beliefs**
Strangers						
Known friends						
Intimate friend(s)						

Table 3.4: List of factors and variables for comfort levels in sharing types of information

Type of Information	**Stanger from different community**	**Stranger from same community**	**Acquaintance**	**Social friend**	**Close friend**	**Intimate friend**
Social						
Academic						
Professional						
Relationships						
Family						

Table 3.5: Emotions experienced in different social contexts

Emotions	**Office**	**School**	**College**	**Wedding**	**Park**	**Commuting (Bus, Train)**
Joy						
Trust						
Optimism						
Love						
Vigilance						
Admiration						
Surprise						
Fear						
Pensive						
Remorse						
Annoyance						
Aggression						

3.3.3 Experimental Set-up for Exploratory Study 2

The experiments were conducted in an enclosed space with the questionnaire kept on a table and the administrator and respondent seated adjacent or opposite to each other (Figure 3.9). The participants were briefed with the objectives of the experiment and after their consent the questionnaire was administered to them.

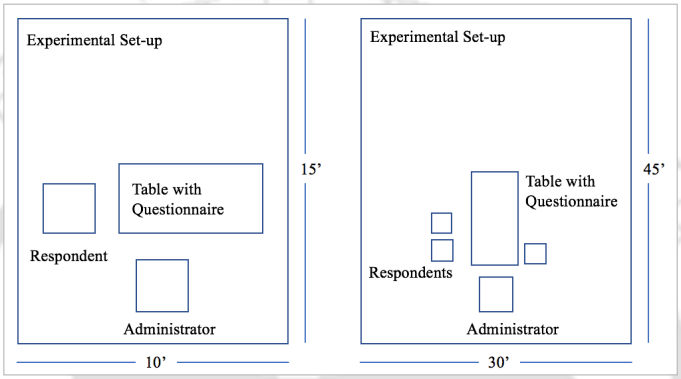


Figure 3.9: Experimental Set-up for conducting Exploratory Study 2

3.3.4 Experimental Procedure for Exploratory Study 2

The respondents filled the descriptive section of describing what according to them is meant by an acquaintance, social friend, close friend and intimate friend. Then they had to mark their response for types of belief systems shared with three kinds of people – stranger, close friend and intimate friend (0=least likely and 10=most likely). Next, was to represent percentage of comfort level (0% is least and 100% is maximum) experienced when sharing information about their social life, academics, professional, relationships and family to strangers of different community, strangers of same community, acquaintance, social friend, close friend and intimate friend. Further, responses for 12 emotions (Joy, Trust, Optimism, Love, Vigilance, Admiration, Surprise, Fear, Pensive, Remorse, Annoyance, aggression from Plutchik's Wheel of Emotions 1980) experienced in six contexts of – Office, School, College, Wedding, Park and while commuting (Bus, train, etc.) in percentage (0% is least and 100% is maximum). Few binary questions followed by descriptions were then answered by the respondents. Figure 3.10 depict participants of the Exploratory study 2.

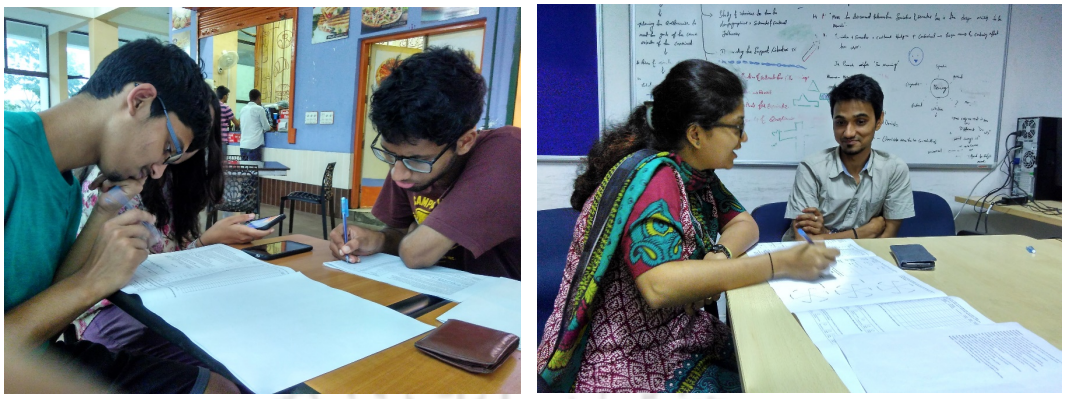


Figure 3.10: Participants of the Exploratory study 2

3.3.5 Analysis of results for Exploratory Study 2

The analysis was carried out on SPSS using reliability analysis and ANOVA for comparison of mean values. Descriptive statistics was used for types of information shared with six different categories of individuals and represented as graphs. Word counting and tabulation was used for descriptive sections – definitions of types of friends and other descriptive questions. This study analyses posit 2.

3.4 Experimental Study 1

Three LED embedded scarves were studied for comparative evaluation. The study lead to testing and consolidation of seven variables for subjective measurement of non-verbal communication with LED embedded scarves in the social space of respondents and a theoretical model for non-verbal expression using LED embedded scarves in the social space of respondents. 3 posits and 1 hypothesis were evaluated in this study. Prior to conducting the Experimental study 1, a preliminary experiment was conducted, as reported in Annexure 6 in detail. During the preliminary experiment, 4 objectives were analysed and the tentative theoretical model for non-verbal self-expression with digital crafts in social spaces was tested and refined for evaluation in Experiment 1. Following this 3 posits and one hypothesis was intended for evaluation in Experiment 1.

3.4.1 Participants and sample size for Experimental Study 1

Total 60 female respondents studying in a national technical institution situated in the North East of India (Table 3.6) took part in the comparative evaluation of prototype scarves 1, 2 and 3. It was carried out in groups of 2-3. Since the results for wearers and

viewers were not significantly different in preliminary experiment, the participants were not divided into *wearers* and *viewers* for marking response on questionnaire, but only for enactment in the social contexts. 42% belong to urban and 58% belong to semi-urban background studying at graduate and post-graduate level. Mean age of participants = 24.56 years and Standard Deviation = 3.16 years.

Table 3.6: Demography for Experimental Study 1

Size (number)	Age group	Place of origin	Educational Background
60	18-32 years	Semi-urban (25), Urban (35)	Undergraduates and Post Graduates

3.4.2 Experimental Design for Experimental Study 1

Five parameters were evaluated Emotions evoked (Plutchik, 1980), Non-verbal Communication (Goleman, 2006), Aesthetics (Blijlevens, et al., 2017), Technology Acceptance model (Davis, 1989) and Usability (System Usability Scale, 2018) as will be reported further. 10 emotions (*Happiness, Optimistic, Awesome, Interesting, Admirable, Sad, Pessimistic, Boring, Annoying and Disgusting*) were rated on a 5-point Likert scale (1=low, 5=high). Look, colors, aesthetics, motifs, design of the LED scarves were rated on corresponding scales of *emotions evoked* and *aesthetics*. Non-verbal communication was measured by the 7 questions as the preliminary experiment. System Usability Scale was used to measure usability. Aesthetics (Blijlevens, et al., 2017) was measured by the following attributes – Attractive, Desirable, Beautiful, Pleasing and Enjoyable – were rated on a 5-point Likert scale (1=low, 5=high). Technology Acceptance Model (Davis, 1989) with six parameters each of Perceived Ease of Use and Perceived Usefulness were rated on a 7-point Likert scale (1=least likely, 7=most likely). Perceived Usefulness comprises – *Quicker communication, Improved communication, Improved productivity, Effective communication, Easy communication and Useful for communication*. Perceived Ease of Use comprises – *Learning is easy, Easy for communication, Clear and understandable, Flexible to interact, Easy to become skillful and Easy to use*. The independent variables were the three prototype scarves and the dependent variables were attributes of Emotions, Aesthetics, Non-verbal expression, Technology Acceptance and Usability. Communication here refers to non-verbal communication using the LED embedded scarves in the given social contexts as will be described further. [Please refer Annexure 12 for LED prototype images and renderings].

3.4.3 Experimental Set-up for Experimental Study 1

The experiments were conducted in an enclosed space with the questionnaire kept on a table and the administrator and respondent seated adjacent or opposite to each other (Figure 3.11). The participants were briefed with the objectives of the experiment and after their consent the questionnaire was administered to them. The participants first interacted with the LED embedded scarf 1, 2 and 3 (Figure 3.12-3.14) as described in following subsection of experimental procedure and then recorded their response in the questionnaire provided.

3.4.4 Experimental Procedure for Experimental Study 1

The procedure for conducting Experimental Study 1 was similar to the procedure followed in preliminary experiment (Annexure 6e). 60 participants took part in an interactive session in groups of 2- 3, where they were asked to imagine being in any one or more of the scenarios, such as travelling alone in a metro, bus stops, college library, strolling in a park, etc. The respondents then communicated meanings through colours of Prototype 1, 2 and 3. The study captured the experience and functionality of Prototype 1, when it changes its colours to express certain additional meanings, such as RED glow could mean *I am not comfortable, stop, do not approach, please leave, I am not interested, I am angry, I disagree*, etc. BLUE glow could mean *I am slightly comfortable, I am slightly approachable, I am slightly interested, I am not very pleased, I slightly disagree*, etc. While a GREEN glow could mean *I am comfortable, welcome, one may approach, one may stay, I am interested, I am pleased, I agree*, etc. The wearer had to express themselves while the viewer had to understand the meaning being conveyed by the three colors in any of the scenario being enacted. For instance, If the wearer and the viewer are in a hypothetical scenario of an office, Wearer expresses as *Red*, then the viewer understands that the person is *busy*. If the wearer and viewer are in a hypothetical scenario of commuting in a bus, Wearer expresses as *Red*, then the viewer understands that the person is *not comfortable.* Another example enacted was, the wearer and the viewer are in a hypothetical scenario of a college cafeteria or Library, Wearer expresses as *Green*, then the viewer understands that the wearer is comfortable or approachable. The responses were marked by the respondents to what degree of expression or understanding took place between them while interacting. Figure 3.15 depicts participants of the Experimental study 1.

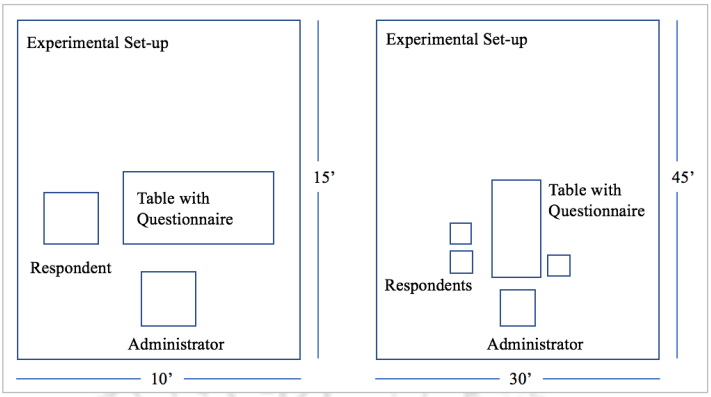


Figure 3.11: Experimental Set-up for conducting Experimental Study 1

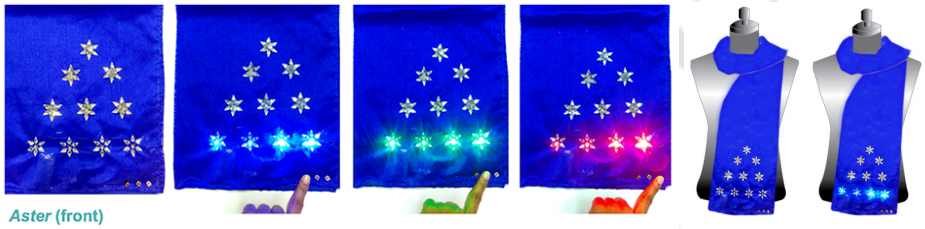


Figure 3.12: Tool- LED embedded scarf 1 for conducting Experimental Study 1

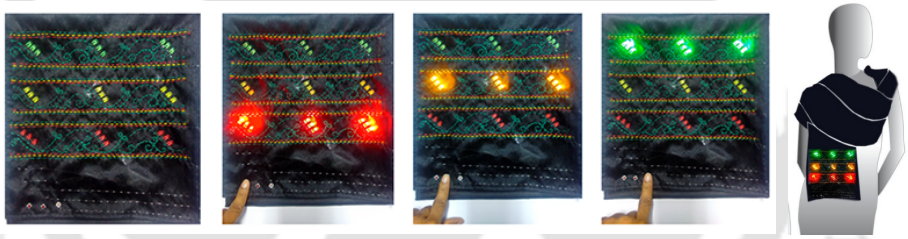


Figure 3.13: Tool- LED embedded scarf 2 for conducting Experimental Study 1

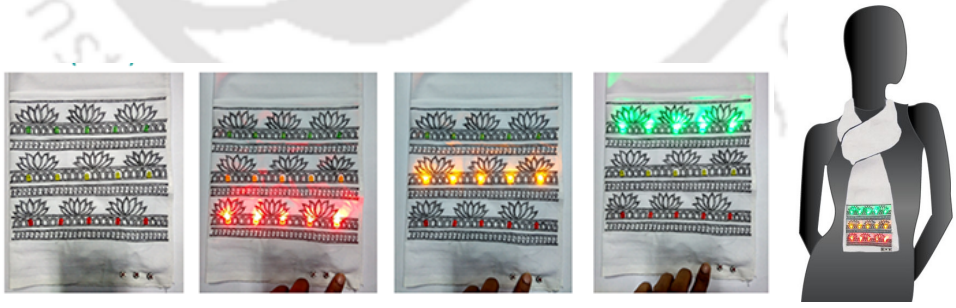


Figure 3.14: Tool- LED embedded scarf 3 for conducting Experimental Study 1

3.4.5 Analysis of results for **Experimental Study 1**

IBM SPSS was used for analyzing results. The data was non-parametric in nature. Friedman's ANOVA was used for assessing Emotions evoked. Spearman's Correlation was used to analyse data for the theoretical model for non-verbal communication to test

and validate values of Aesthetics, Emotions evoked and non-verbal communication correlated with the values of Technology Acceptance Model. Spearman's Correlation is a non-parametric version of Pearson's correlation which is used for parametric data. The correlation coefficient measures the direction (positive or negative) and strength between the variables (Kothari, 2004 and Field, 2009). For a comparative assessment and validation of the NVC model, results of prototypes 1, 2 and 3 were analysed for consistency. Principal Component Analysis was used to establish if the 7 questions captured non-verbal expression using the LED embedded scarves. Comparative assessment was carried out for the three scarves for validation. Spearman's Correlation is a non-parametric version of Pearson's correlation which is used for parametric data. The correlation coefficient measures the direction (positive or negative) and strength between the variables (Kothari, 2004 and Field, 2009). Hypothesis 1 and Posits 3-5 were analysed through this study.

Figure 3.15: Participants of Experimental study 1

3.5 Experimental Study 2

This study was conducted for testing the hypotheses posited after conducting the exploratory studies, experiment 1 and further refinement. The objective is to collect response of young Indian respondents to a traditional *bundi*/jacket capable of changing visual cues/colors by a remote control. The visual cues enable wearer to express meanings – emotions, feelings to people around in certain contexts allowing nonverbal communication in situations where words need not be used to express one-self subtly. This capability of textile wearables for non-verbal self-expression is being captured by the experiment being conducted. The study was conducted with 124 graduate and postgraduate students studying a national institution for fashion design, accessory design and fashion management studies, located in the North-East of India. A static jacket (without LEDs) and

a LED tee shirt with verbal messaging was also used for comparison with LED jacket. The study significantly indicates that a dynamic LED jacket is capable of expressing emotions and feelings in the social context of the wearer.

3.5.1 Participants and sample size for **Experimental Study 2**

A total of 124 participants took part in Experimental study 2 (Table 3.7). The participants were studying in a national fashion institution located in the North-East of India at design graduate and fashion management post-graduate level. 60% of them belonged to semi-urban background and 80% of them were more experimental with fashion and new products. Mean age of participants = 21.42 years and Standard Deviation = 2.16 years.

Table 3.7: Demography for Experimental Study 2

Size (number)	Age group	Place of origin	Educational Background
124	18-32 years	Semi-urban (74), Urban (50)	Undergraduates and Post Graduates

3.5.2 Experimental Design for **Experimental Study 2**

12 Emotions (6 positive – Happiness, Optimism, Awesome, Interesting, Admirable and Surprised; 6 negative emotions – Sadness, Pessimism, Boring, Annoying, Disgusting and Angry) were rated on a 5-point Likert scale for both the static and the dynamic jacket with LEDs with respect to the 8 colors (Red, Green, Blue, Teal, Purple, Orange, Yellow and White). 7 feelings had to be rated on a 5-point semantic differential scale (Disagree-Agree) with respect to the static and the 8 colors of the dynamic jacket (Figure 3.16). Questionnaire comprises six parts: (i) 12 Emotions (6 positive - Happiness, Optimism, Awesome, Interesting, Admirable, Surprised; and 6 negative - Sad, Pessimistic, Boring, Annoying, Disgusting, Angry; from Plutchik's Wheel of Emotion) evoked by static jacket and feelings expressed by static jacket rated on a five point Likert scale (1=very low, 5=very high); (ii) The 12 Emotions evoked by the 8 colors (Red, Blue, Green, Teal, Purple, Orange, Yellow, White) in the respondents, five point Likert scale (1=very low, 5=very high); (iii) Feelings expressed by the model in the cafeteria pictures in 8 different colors as understood by the respondents during photo elicitation, rated on a five point Likert scale (1=very low, 5=very high); (iv) Feelings respondents would have expressed had they been in place of the model at the cafeteria, five point Likert scale (1=very low, 5=very high); (v) System usability scale for the LED jacket; and, (vi) Descriptive section for comments,

suggestions, etc and one binary question of choosing one of the two as the preferred method for self-expression in certain social spaces and contexts – verbal or non-verbal. The independent variables are the visual cues of the static and dynamic jacket and the dependent variables are attributes of *Emotions* and *Feelings* to be rated corresponding to the stimuli.

Emotions	1 Very low	2 Low	3 Neutral	4 High	5 Very High
Happy					
Optimistic					
Awesome					
Interesting					
Admirable					
Sad					
Pessimistic					
Boring					
Annoying					
Disgusting					
Angry					
Surprised					

Feelings	1 Disagree	2 Slightly Disagree	3 Neutral	4 Slightly agree	5 Agree
I am relaxed					
Leave me alone					
I am waiting for friends to join					
I am thinking deeply					
I'm ok to chat with anyone					
I am angry					
I am in a good mood today					

Figure 3.16: Matrices for rating Emotions and Feelings with respect to static and 8 colors of dynamic jacket

3.5.3 Experimental Set-up for **Experimental Study 2**

The experiment was carried out in an enclosed space where respondents were seated in batches of 20-30 at a time (Figure 3.17). The tools used were – a static jacket with hand done embroidery (Figure 3.18-3.19), another jacket with LEDs attached to it inside

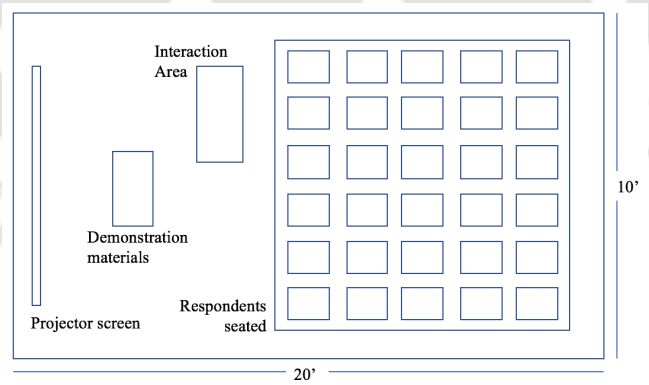


Figure 3.17: Experimental Set-up for conducting Experimental Study 2

that could change colors with a wireless remote control (3.20-3.21), a LED tee shirt which could display verbal messages when typed on phone (3.22), and a questionnaire to mark responses. A jacket was designed in this experiment as the scarves designed for the previous experiment could be used only by female respondents, while the jacket could be worn by both male and female respondents.


Figure 3.18: Tool- Static jacket; **Figure 3.19:** Model wearing static jacket at a cafeteria

Figure 3.20: Tool- Dynamic jacket; **Figure 3.21:** Model wearing dynamic jacket at a cafeteria

Figure 3.22: Participants wearing LED tee shirt with verbal messages

3.5.4 Experimental Procedure for **Experimental Study 2**

A small brief was presented on a projector screen with the background of research, state of the art in the field of LED textiles, aim, objectives and overall methodology of the experiment. Following this the static jacket was given to them to be worn and then mark

their response in the questionnaire provided pertaining to emotions evoked and if the jacket conveyed the 7 listed feelings, rated on a five-point Likert scale. Further the LED jacket was first demonstrated and given to the participants to wear and interact for 5-10 minutes each. The respondents then marked their response for Emotions evoked in them according to the eight different colors of the LED jacket. Feelings had to be first marked in response to the model seated in a group at a cafeteria. This was a photo-elicitation part where the model has neutral expression on face while expressing herself only through the colors of

Figure 3.23: Participants of the Experimental Study 2

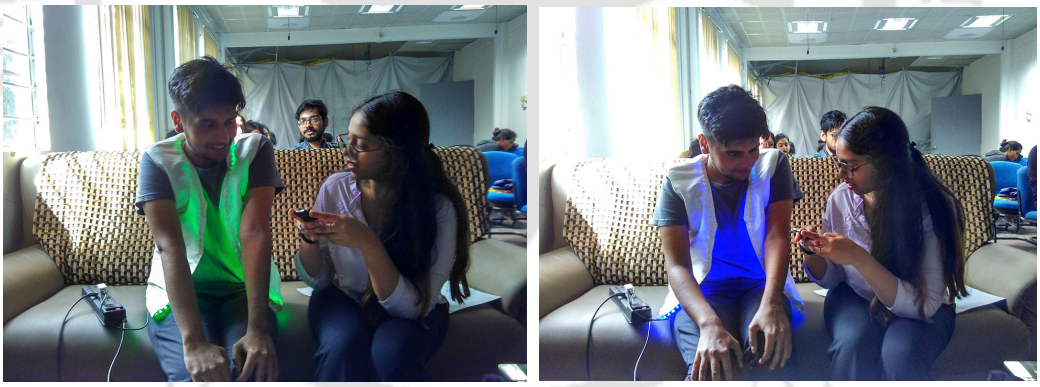


Figure 3.24: Participants interacting with the LED jacket – Experimental Study 2

the LED jacket. The respondents rated feelings expressed by the model as perceived by them. In the next part, respondents had to imagine themselves seated in place of the model at the cafeteria, and rate which colors could express the *feelings* listed in the questionnaire. The LED tee shirt that displayed verbal messages was demonstrated. The respondents marked their preference for either non-verbal expression (for instance using visual or tactile cues like that of the LED jacket) or verbal expression (for instance as that of the LED messaging tee shirt as demonstrated). Further they noted their views, opinions, suggestions, etc. in the descriptive section. Figure 3.23-3.24 depict participants of Experimental study 2. [Please refer Annexure 9-10 for questionnaire and Annexure 12 for prototype images].

It is important to note the role of social space in the procedure of the experiment. Social space in this thesis has been defined as a defined space around the user where interactions are taking place. In this experiment, the photo elicitation defines the social space as the cafeteria where the model wearing the jacket is seated with a mixed group of known and unknown people. The model expresses herself in course of interaction the photographs through visual cues (colors) of the jacket. The respondents have to understand the 8 different cues and mark their response as per what they perceive the visual cues (colors as stimuli) for expression of emotions and feelings in the photograph. In the next part, the respondents imagine themselves being a part of the same social space, a cafeteria, as in the photographs, and mark their response as to what they would like to express though the visual cues if seated in the same scenario.

3.5.5 Analysis of results for Experimental Study 2

Analysis was carried out on IBM SPSS using Friedman's ANOVA and post hoc analysis, the data being non-parametric. Friedmans' ANOVA is a non-parametric version of ANOVA (used for parametric data) for analysis of variance based on mean comparison (Field, 2009). Descriptive statistics were used to represent color representations of emotions and feelings and preference of users for verbal or non-verbal expression. Hypothesis 2 and 3 were tested through this study.

Chapter Summary: *This chapter discusses the methodology followed to carry out the preliminary exploratory studies and the three experimental studies for evaluation and validation of hypotheses. The measurement scales, parameters, experiment layouts, procedures and tools used have been outlined. The data collected from these studies has been analysed and reported in the next chapter.*

Chapter 4

Exploratory Studies and their Implications in designing wearables

This chapter reports findings of Exploratory study 1 and 2 conducted to understand young Indian user perception of traditional textiles of India and their behavior while interacting with other individuals in their social space. Implications of these studies in designing wearables as digital crafts has been discussed and then designing of design of four digital craft prototypes for conducting user evaluation has been reported.

4.1 Introduction

Chapter 3 explains the research methodology followed to conduct experiments, data collection and analysis for conducting present research. The objectives of this chapter are to conduct exploratory studies to gather data on user perceptions about traditional textiles and behavior in social space which could provide directions for designing tools for conducting experiments and testing posits and hypotheses posed in this research. Exploratory study 1 studies perception of 60 young college going respondents about 12 sarees of India, preferences for motifs, color connotations, moods and emotions evoked in them and what these textiles reveal about the personality of the wearer, derived out of a photo elicitation based cultural probe. Exploratory study 2 understands how young college going male and female respondents create boundaries around themselves for sharing information with different kinds of people, emotions experienced in different social contexts, comfort levels experienced in sharing different types of information with different categories of people and types of information revealed to different categories of people. Based on the findings digital craft prototypes were designed based on User Centered Design process to express emotions and feelings in specific contexts and was evaluated with college going students as part of two experimental evaluation which will be discussed in Chapter 5. Following are the findings of Exploratory studies 1 and 2 and the designing of digital crafts.

4.2 Exploratory Study 1 – Perception of traditional textiles of India among users

The study aims at deriving insights regarding the traditional wear trends of women between 18-28 years of age. The images used have been chosen by the same age group as

per their preferences. The study gathers information about emotions evoked in respondents upon viewing a set of traditional sarees, their colors and patterns. Information collected from around 30 respondents provided key insights about preferences of women for handloom and handcrafted sarees.

Definition of mood was given as 'state of mind' by 10 respondents. Others described 'mood' as 'feeling of mind'; 'thinking about a situation'; 'emotion we are feeling just now', 'emotion'; 'human behavior or reaction looking at a situation'; 'emotions a person goes through in a day'; 'state of stress or de-stress'; 'inner feelings'; 'heart's feeling beyond description'; 'state of mind which depends on internal or external factors' and 'change in attitude'.

90% of respondents stated that colors in the dress changed their mood and that dresses worn uplift their mood. 80% of the respondents agreed that they make a conscious decision while buying a dress. Dress worn is an extension the personality for 83.33% of respondents. Only 60% said that they were aware of buying dresses in different moods, while 40% were not sure whether they bought differently in different moods.

31% respondents preferred a solid colored (i.e. singe colored) saree with a decorated border of any kinds of motifs, such as geometric, floral, *butis*, etc. (Figure 4.1, vertical axis shows percentage of respondents). 19% preferred florals, paisleys and solid colors and 15% preferred geometric and another 15% preferred mythological motifs, such as scenes from Mahabharata, palanquins, etc. on sarees.

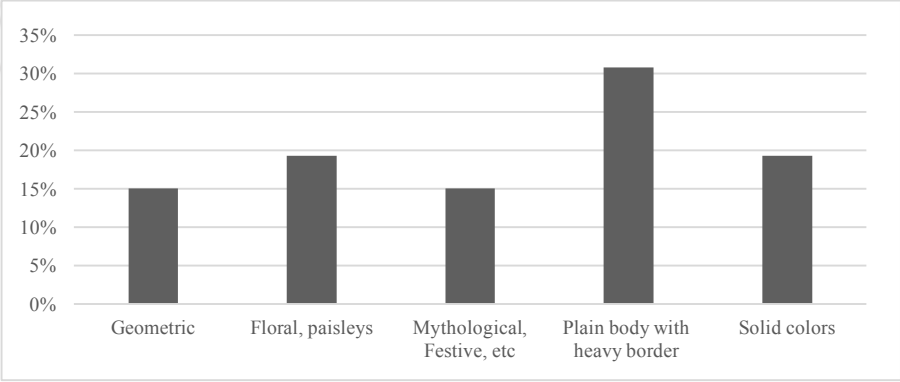


Figure 4.1: Preference for motifs on a traditional saree

Red, maroon and combinations of *green, gold* with *red* were chosen most. *Blue* and *Royal blue* ranked second in the choice for traditional saree. *Magenta, pink* and *purple* ranked third. *White, off-white* and *cream* along with *yellows* ranked fourth, chosen by 4 respondents each. *Green* and *black* were preferred by very few respondents.

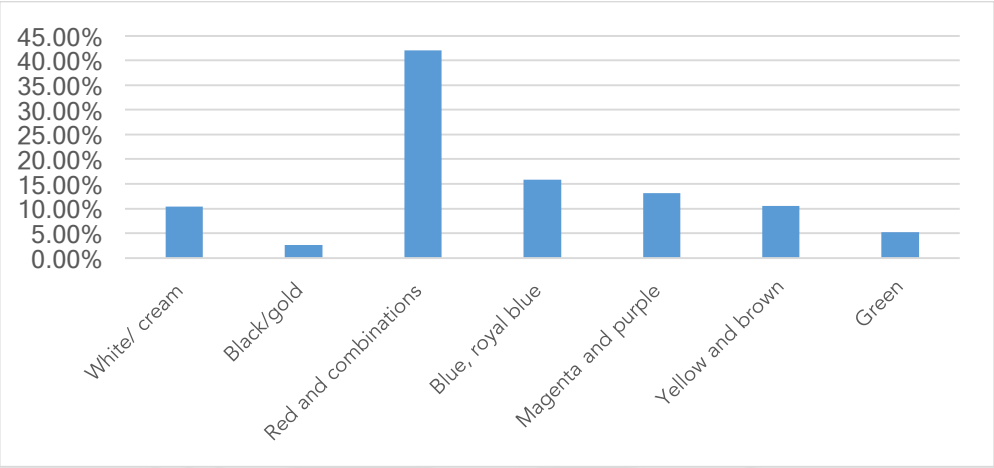


Figure 4.2: Colors chosen for traditional saree

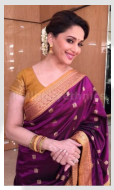
4.2.1 Mood-color-saree correlation

Following is a table where *moods* were described by the users with colors, first and then they chose to represent the moods with the 12 sarees in the tool kit (Table 4.1). Few colors of sarees like *light blue, black, brown* were not available in the tool kit. It was found that colors chosen and sarees chosen did have similarity in representing the moods. It is important to note that sarees and colors were not picked simultaneously, first the colors were chosen and then the sarees were chosen. The associations have been linked as strong, medium and not associated on the basis of word count. Out of the ten *moods* - 3 strong associations, 3 moderate associations and 4 nil associations were identified. The highest two or three responses in percentage for colors has been chosen. Other colors were one or two choices in each case, hence have not be included in the table.

Table 4.1: Associations between moods, colours and sarees according to the respondents

Sr no.	Moods	Colours	Sarees chosen by respondents	Association
1	Good	28% blue 16% pink	 19% 16% 14%	Moderately Associated A blue saree was not in the tools used, however, a pink/magenta saree was present. White saree with gold border represents festivity in many cultures in India.

2	Bad	30% brown 13% black	 21%  15%	Not associated From the sarees shown, dull blue and dark green sarees were chosen to represent bad mood. Brown and black saree were not used as tools.
3	Lazy	33% grey 20% yellow	 26%  26%	Strongly Associated Mustard yellow and dull blue grey were chosen by majority as lazy.
4	Cheerful	17% yellow, 20% pink, 20% red	 23%  19%	Stronlgy Asscociated The gold of the sarees and red were top preferences for represnting cheerfulness.
5	Depressed	28% black, 14% white	 25%	Not Associated A black saree might not represent depression as much as a plain white saree worn for mourning, etc. However such sarees were not used as tools.
6	Adventurous	17% black, 17% red	 15%  13%	Not Associated Though the color red is very energetic, red saree is more appropriate for festival or wedding. Black

				saree was not used as tool.
7	Ease	23% pink, 20% white	 22%	Not Associated White sarees shown were more energetic and festive so did not relate to easiness.
8	Rejuvenated	23% blue, 14% white	 14%	Moderately Associated White saree was found to be rejuvenating along with festivities and happiness. Blue saree was not used as tool.
9	Enjoyment	43% red, 13% pink	   28% 21% 16%	Stronlgy Asscociated Red and Pink sarees reflected enjoyment.
10	Satisfaction	27% blue, 27% white	  15% 16%	Moderately Associated Blue saree was not used as a tool.

4.2.2 Emotions evoked

Ten Emotions were rated by the respondents on a seven Likert scale extremely high, very high, high, average, low, very low and extremely low for all twelve sarees. The Cronbach's Alpha for reliability for the 12 sarees and *emotions evoked* was 0.886 on SPSS (Statistical Package for Social Sciences). The white saree with gold border and the magenta saree were the two most preferred sarees that were chosen for various responses, response for emotions have been shown for two sarees (Figure 4.3-4.4). These emotions were taken from the Plutchik's wheel, 1980. Only the relevant positive and negative emotions from

the wheel have been considered. The positive emotions such as *Admiration, Amazement, Joy, Serenity, Interest, Awe* were high and negative emotions such as *Boredom, Sadness* and *Apprehension* were low. The entire mood is being created by a set of emotions, for instance *Admiration, Amazement, Joy, Serenity, Awe* and *Interest* together create happiness, festivity, ethnicity, celebration and optimism. Which implies that to create happiness or festivity, through textiles, emotions such as *admiration, amazement, joy, serenity, awe* and *interest* could be worked upon with the use of certain colours, combinations, motifs etc. by designers while designing or crafting textiles.

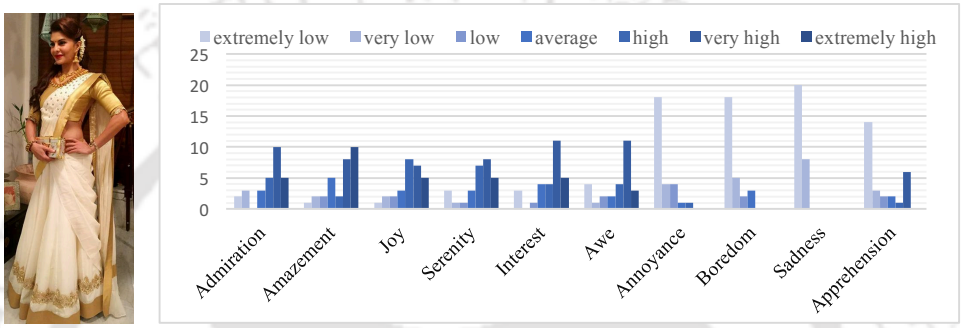


Figure 4.3: Emotions evoked by white saree with gold border (7 scale)

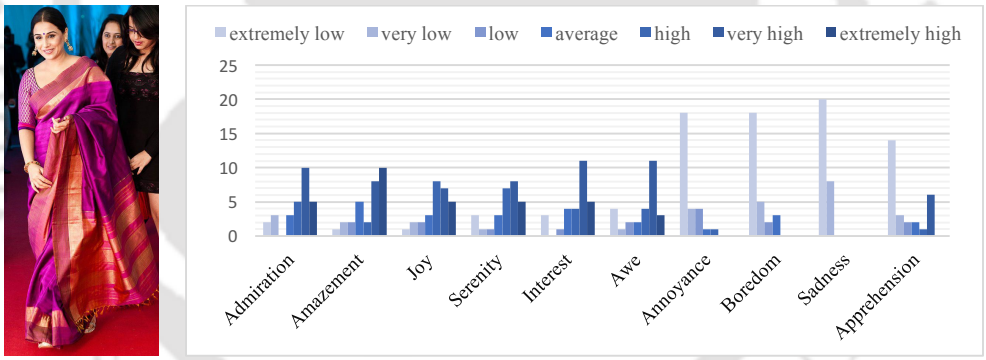


Figure 4.4: Emotions evoked by the magenta saree (7 scale)

Citing two othe examples, from the set of 12 sarees (Figure 4.5-4.6), positive emotions were evoked higher than negative emotions for all sarees. 76% respondents *admired* the red bridal saree (Figure 4.5, vertical axis shows number of respondents), 70% respondents found the saree *amazing* and *joyous*, 60% respondents found the saree *serene*, 67% respondents found the saree *interesting*, 73% respondents were *awed* by the saree – on a scale of *high* to *extremely high*. For negative emotions, 13% respondents found it boring and oft repeated combination for bridal wear while 10% respondents found it to be *apprehensive*. Majority rated *low to extremely low* for negative emotions.

Similar response was seen in case of purple saree (Figure 4.6), where positive emotions were rated higher and negative emotions were rated lower on the Likert scale as shown in

the graph. These readings indicate a method to capture emotions evoked on a subjetcive scale which can be studied on a larger sample to understand the capacity of textiles in evoking emotions in the viewers and the wearer. Cultural background of the respondents played a key role in determining the positive and negative emotions in the participants.

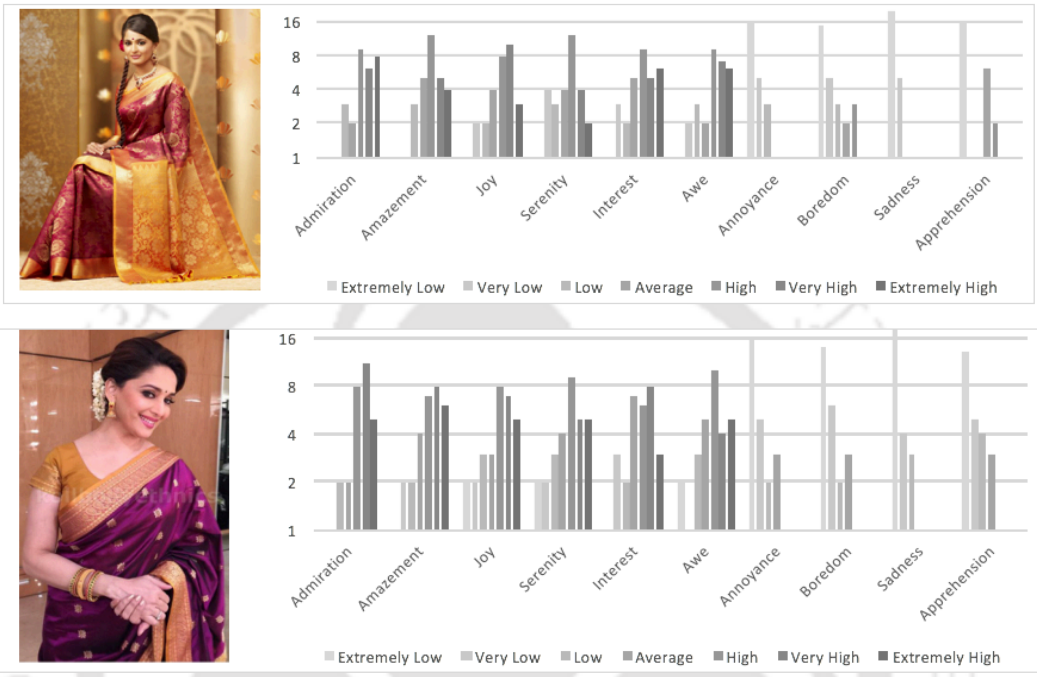


Figure 4.5 (top) and **Figure 4.6** (bottom): Graph showing results of 7 point likert scale for rating emotions evoked by sarees

50% of the respondents hailed from East and North-East, 25% form the North, 15% from the South, and, 5% from Central and Western parts of India. In the North-East and South, white and beige sarees are considered auspicious and are worn at wedding, ceremonies and festivals. While clothing with white or beige colors are considered inauspicious for married women by some for the North, West and Central parts of India for particular occasions, as described by the participants. Men and children often wear white clothing for festivals, specific occasions or as daily wear. Hence the respondents accordingly marked their response with respect to positive and negative emotions evoked in them.

4.2.3 Color connotations

A 12 color swatch set derived from the color families that the sarees belonged to, was given to respondents to describe in one or more words, what each color meant to them. The words have been categorised as positive and negative connotations, nine colors and

respective responses have been mentioned in Table 4.2. The numbers within brackets adjacent to the words is the count for repition in response. The cultural background, experiences and personal preferences of respondents influence the color comprehension significantly. For example *white* is *peaceful*, *divine* and *pure* for most while it is also associated with *sadness*. According to the respondents, this is particularly because *white* is worn by women for wedding and festive occasions combined with *gold* and other colors in the south and east of India. *White* is also worn for mourning a death or to express grief in the North of India. However, Men wear white for any important occasion – wedding or any cultural or family functions across different regions the country. Similarly *gold* is *brilliant*, *royal*, *attractive*, *gorgeous* for most, but *boring* because it is commonly used for most festive occasions and is repititive, as the respondents mentioned. Gold and silver are commonly used for jewelry, idols for worship, used in exclusive occasions, hence described as *royal, godliness, divine, festive* by the respondents. *Red* is an auspicious color which is used widely for wedding and festive occasions, hence associated with terms such as - *love, gorgeous, passion, happiness, excitement and beauty*. Meanings of colors – *Red, Blue, Yellow, Green, Purple, Brown, Black, White, Grey, Gold, Silver and Tints* – were represented by two-three associated terms. Of the 332 total attributes listed including repetitions, 268 were positive and 63 were negative associations; i.e., 81% positive terms and 19% negative terms listed. Few most repeated terms for 8 colors have been listed in Table 4.2.

Table 4.2: Meanings associated with colors by the respondents

Color	Positive	Negative
Red	Love (5), Bold (2), Energetic (2), Wedding (2), Festive, Traditional, Gorgeous, Desire, Passion, Intense, Excitement, Adventure, Cheerful, Happy, Joyful, Confident, Beauty	Dangerous (4), Anger (4), Fear (2), Depressing
Blue	Calm (4), Happiness (4), Peace (3), Cool (2), Refreshing, Rejuvenating, Pleasant, Elegant, Confidence, Beautiful, Infinity, Energetic, Aquatic, , Artistic, Fantasy, Casual, Enjoyment, Nature, Easy going, Decency, Good	Lazy
Yellow	Happy (5), Cheerful (3), Bright (3), Festive (2), Friendship, Peaceful, Lively, Eye-catching, Cute	Depressed (2), Annoying (2), Pale, Fidgety, Mediocre
Green	Serenity (3), Fresh (3), Nature (4), Environment (2), Pure, Rejuvenation, Enthusiastic, Quiet, Elegant, Positivity, Calm, Airy, Joy, Life, Enjoyment, Happy, Easy-going, Satisfaction	

Purple	Festive (3), Fantasy, Quality, Richness, Love, Romantic, Lively, Adventure, Casual, Girly, Cool, Peppy, Happy	Boring (2), Sad
Black	Bold (3), Gorgeous (2), Elegance (2), Classic (2), Power, Style, Ancient, Confidence, Boldness, Rich, Sharp, Energetic, Serenity, Calm	Depressing, Sad (2), Dark (2), Lonely, Annoying
White	Peace (10), Divine (2), Pure (2), Respect, Elegant, Soothing, Positive, Silence, Style, Inspiration, Ancient, Lightness, Clean, Official, Pretty, Sober, Happy, Simplicity	Sad
Gold	Festive (7), Jewelry (4), Royal (2), Attractive (3), Pride, Brilliance, Vibrant, Exclusiveness, Precious, Gorgeous, Grand, Expensive, Richness, Flashy, Enjoyment, Shiny	Boring
Silver	Jewellery (3), Pure, Brilliance, Serene, Godliness, Divine, Gorgeous, Classy, Elegant, Festive, Inspiration, Expensive, Attractive, Beautiful, Good, Cheerful	

Color itself is quite comprehensive a subject to study with respect to textiles or traditional textiles due to its significant contribution pertaining to cultural diversity in India and elsewhere. In the present thesis, since the preliminary study, the focus of colors has been explored in terms of capacity to evoke moods, emotions and understanding color connotations of young users to be able to develop experimental set-up – prototype, LED colors for expression of meanings for experimental studies. This was done to route the purpose of studying color to contribute in subsequent stages considerably.

4.2.4 Personality traits

As studied in literature personality traits have been found to be influenced by traditional textiles as revealed in the user study. It is also seen that certain attributes such as *beautiful* represent a personality trait, an opinion, a judgement and is also an attribute for aesthetics, synonymously used by the respondents.

To a question asked to desrcibe the contemporary sarees with traditional motifs and colors worn by the models, respondents expressed their opinions as adjectives and personality traits, in one or more words. Giving a set of pre-defined words would not have revealed the wide range of words that a culturally disctint set of respondents may have provided. The analysis of the words provided by the respondents creates a vocabulary of descriptive words for traditional sarees. The words have been categorised as positive and negative

connotations (Table 4.3). The numbers within brackets adjacent to the words is the count for repition in response. For example, while the first magenta saree is *elegant*, *gorgeous, graceful* for many; *beautiful, classic* and *nice* for most; the bright magenta solid color was also *disguting* and *uncomfortable* to two respondents. Similarly the red wedding saree was *beautiful, elegant, gorgeous* for most but *boring* for two respondents, as it is a common combination used for a wedding trousseau. The analysis reveals how wearing a particular saree leads to definition of personality traits of the wearer as judged by the viewers. It was found on the basis of word counting that positive traits were listed more than the negative traits. Of 350 attributes in total (including repetition), 311 attributes were positive and 39 were negative descriptions, i.e., 89% were positive and 11% were negative attributes as listed. Most repeated positive attributes include – *Beautiful, Elegant, Happy, Gorgeous, Classic* and *Confident*. Few negative attributes include – *Depressed, Dull, Boring, Uncomfortable* and *Overdone*.

Table 4.3: Perception of sarees worn by models as described by the respondents

Saree	**Positive Connotations** **Multiple response**	**Single response**	**Negative Connotations**
	Beautiful (5), Classic (5), Elegant (4), Gorgeous (2), Good (2), Simple (3), Happy (2)	Vibrant, Graceful, Confident, Formal, Excited, Minimalistic, Respectful, Wonderful, Nice, Decent	Uncomfortable, Disgusting
	Gorgeous (5), Elegant (3), Good (3), Very beautiful (3), Awesome (2), Confident (2)	Classic, Cheerful, Amazing, Ethnic, Perfect, Sophisticated, Serene, Beautiful, Attractive, Pretty, Energetic, Decent, Nice, Average	Overdone, Nervous
	Beautiful (4), Classic (2), Cheerful (2), Pretty (3), Nice (2)	Motherly, Calm, Ethnic, Confident, Pleasant, Soothing, Gorgeous, Beautiful, Graceful, Elegant, Awesome, Happy, Good, Sweet, Decent, Fine	Fake
	Beautiful (5), Elegant (4), Decent (3), Gorgeous (3), Gorgeous (2), Awesome (2)	Joyful, Nice, Simple, Fine, Calm, Sophisticated, Royal Aura, Refreshing, Cheerful, Expressive	Boring (2), Old-fashioned
	Simple (2)	Decent, Pretty, Stylish, Casual, Smart, Carefree, Nice, Cool, Average, Great, Independent, Unorthodox, Beautiful, Comfortable, Formal, Simple, Official, Smart	Dull (2), Sad (2), Ugly, Dizzy, Scared, Boring

	Bold (4), Classy (3), Simple (3), Nice (3)	Woman of substance, Amazing, Calm, Formal, Comfortable, Smart, Beautiful, Elegant, Pretty, Average, Good	Angry (4) Arrogant, Cunning, Aggressive, Pathetic

4.2.5 Discussion of posit

As studied from various literature sources, the use of motifs, colors and embellishments have been symbolic and derived from nature, mythology or daily life. Handcrafted textiles are an integral part of societal and cultural heirloom, not just as artefacts but also the skills of craft making that has been passed down from one generation to another. Based on the analysis of the user study conducted, it follows that textiles do evoke a set of emotions which are predominantly positive (Figures 4.3-4.6). Also, the meanings associated with color families that the sarees belong to (Table 4.2) and the personality traits as described by the respondents (Table 4.3) were observed to be associated essentially with positive connotations than negative. It can thus be inferred that textiles have significant potential in terms of inducing a detailed cognitive process inside the wearer and the viewer both. This process leads to formation of attitude, opinion and judgement of wearer's personality. The textiles significantly evoke a series of emotion in users, which might not be explicit unless the subjective matter is captured on a scientific scale of measurement. Cultural background and individual preferences generate a wide range of results; due which qualitative analysis reveals more information about individual responses. Further studies could be conducted with textile samples and larger sample of respondents for deeper insights and analysis of how traditional textiles affect our emotional state, perception, personality and preferences.

The Exploratory Study 1 thus leads to evaluation of **Posit 1 – Traditional textiles positively influence emotions, personality, attitude, opinion, preferences and self-expression among young female users in India.**

4.3 Exploratory Study 2 – Behavioral study on social interaction among young users

Findings discussed below include the traits possessed by *friends* as mentioned, levels of information revealed to different categories of individuals, boundaries

respondents create around themselves, emotions experienced in specific contexts and comfort levels experienced while sharing information about themselves with different categories of individuals. The focus is to derive insights for designing textile wearables that could communicate boundaries, comfort levels and emotions in the social space of the user, in specific contexts only when required, through subtle yet explicit non-verbal expression.

4.3.1 Definitions of categories of friends

Respondents were asked to describe what kind of traits *Acquaintance, Social friends, Close friends* and *Intimate friend(s)* should possess and how would it be different between real-life and digital platforms (Table 4.4). *Acquaintances* were found to be distant and involve in rare to occasional interactions. *Social friends* belong to an extend circle of friends, or are friends' friends with whom respondents interact frequently. *Close friends* are ones that belonged to a personal circle, and respondents are comfortable with and interact regularly than social friends. *Intimate friend/ friends* are the ones respondents shared closest bonds and are deeply connect. It been seen from the table that more descriptions are provided for real-life friends than the online friends due to stronger bonds shared between the users.

Table 4.4: Traits that following friends should possess in the opinion of the respondents

Category	Responses
Acquaintance	Two respondents mentioned they should be *Respectful* and Well *mannered*. Other descriptions include - *An occasional 'Hi' & 'Bye', Small talks, Non-interfering, No expectations, Positive, Resourceful, and Sense of humor, Should respect others' privacy, and Should talk nicely, Non-judgmental.*
Social Friend	Four mentioned *Helpful* and *Caring*, two mentioned *Friendly, Acceptable*, *Honest* and *Understanding*. Other descriptions include -*Available to talk occasionally, Good sense of humor, Cheerful, Dependable, Friendly, Humorous, Happy, Humble, Mutual understanding, Notorious, Non-judgmental, Should be interfering, Good natured, Should have met in school/college/ workplace, Should spend some time with you, Responsible, Trustworthy.*
Close friend	Seven respondents mentioned their friend should be *Caring*. Five mentioned *Funny*. Four respondents mentioned *Honest* and *Understanding* and two mentioned *Loving, Trustworthy, Non-judgmental, Supportive and Dependable.* Other descriptions include - *Friend with whom I can share my problems, Fun loving, Good vibes, Helpful, Loyal, makes me happy, Mutual understanding,*

	Patient, Reliable, Should have the quality of compromise, Talk about almost everything.
Intimate friend	Eight respondents mentioned *Understanding*. Five respondents mentioned *Caring*. Five respondents mentioned *Trustworthy*. Three respondents mentioned *Supportive, Loving*. Two respondents mentioned *Honest* and *Funny*. Other descriptions include - *Ambitious, Calm mostly, Comfortable to be around, Dependable, Emotionally connected, Faithful, Feminist, Genuine, Good listener, Someone who is there when needed, Entertaining, Helpful, Important, Joyful, Loving, Loyal, Real, Reliable, Non-judgmental, Understanding, Should spend maximum time with you, Intellectual.*

4.3.2 Boundaries around the users and Feelings experienced in different contexts

To understand the personal boundary limits respondents, create for sharing their belief systems – *Intellectual, Emotional, Sexual, Material, Political* and *Physical* with *Intimate friend(s), Known friends* and *Strangers*, they were asked to mark a point on the respective radius of the circle (Figure 4.7). The center of the circle denotes least value (0) and periphery denotes highest value (10). The response revealed that majority share their beliefs openly with intimate friends, moderately with known friends and restrictively with strangers. Only 3-4 respondents share beliefs restrictively with intimate friends and openly with strangers. The data has been represented in a radar diagram and was also analyzed quantitatively on SPSS. The Cronbach's Alpha for reliability was 0.883. ANOVA results showed significant values as described in Table 4.5.

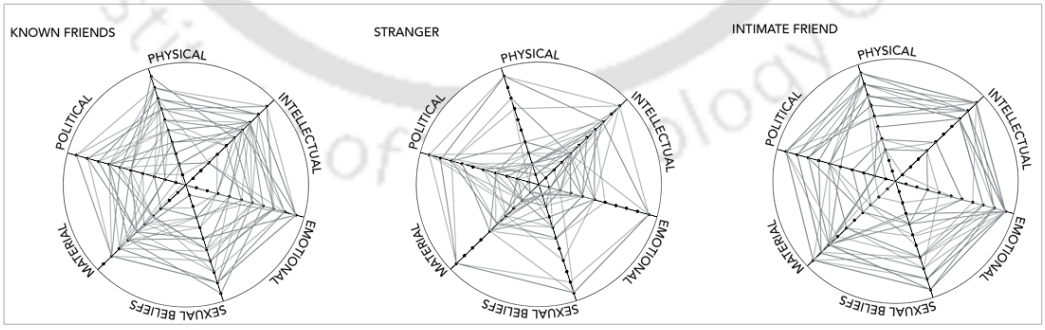


Figure 4.7: Boundaries respondents create for sharing information

Table 4.5: ANOVA results for boundaries of sharing information

Beliefs		Sum of Squares	df	Mean Square	F	Sig.
Physical	Between Groups	256.089	2	128.044	21.271	.000

	Within Groups	523.700	87	6.020		
	Total	779.789	89			
	Between Groups	114.689	2	57.344	11.878	.000
Intellectual	Within Groups	420.033	87	4.828		
	Total	534.722	89			
	Between Groups	319.356	2	159.678	29.952	.000
Emotional	Within Groups	463.800	87	5.331		
	Total	783.156	89			
	Between Groups	161.156	2	80.578	8.816	.000
Sexual	Within Groups	795.167	87	9.140		
	Total	956.322	89			
	Between Groups	171.022	2	85.511	15.500	.000
Material	Within Groups	479.967	87	5.517		
	Total	650.989	89			
	Between Groups	62.956	2	31.478	3.796	.026
Political	Within Groups	721.500	87	8.293		
	Total	784.456	89			

4.3.3 Comfort levels experienced by users and types of information being shared

Respondents had to mention their comfort on a scale of 0-100 (0-20 very low, 21-40 low, 41-60 average, 61-80 high and 81-100 very high) while interacting with six categories of people namely – *stranger from different community, stranger from same community, acquaintances, social friend, close friend* and *intimate friend* for sharing information such as – *social life, academics, professional life and relationships*. The Cronbach's Alpha value for reliability test of the data collected was 0.843 on SPSS. ANOVA results revealed that respondents were restricted in sharing information with strangers from different community, same community and acquaintances. Comfort levels with intimate friends was high for some and low for some respondents, response thus was not significant as mentioned in Table 4.6.

Table 4.6: ANOVA results for comfort levels expressed by users

Categories		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Different Community	Between Groups	15197.000	5	3039.400	5.433	.000
	Within Groups	97343.200	174	559.444		
	Total	112540.200	179			
Same Community	Between Groups	16729.444	5	3345.889	5.770	.000
	Within Groups	100891.800	174	579.838		
	Total	117621.244	179			
Acquaintance	Between Groups	27066.111	5	5413.222	7.598	.000
	Within Groups	123975.000	174	712.500		

	Total	151041.111	179			
	Between Groups	23509.028	5	4701.806	5.657	.000
Social Friend	Within Groups	144612.500	174	831.106		
	Total	168121.528	179			
	Between Groups	9302.361	5	1860.472	3.020	.012
Close Friend	Within Groups	107199.167	174	616.087		
	Total	116501.528	179			
	Between Groups	2639.028	5	527.806	1.603	.162
Intimate Friend	Within Groups	57285.833	174	329.229		
	Total	59924.861	179			

4.3.4 Feelings experienced in different contexts

Further, respondents were asked to represent emotions *of joy, trust, optimism, love, fear, pensive, annoyance* and *aggression* that could be expressed at *office, school, college, wedding, park* and *while commuting*. The qualitative analysis has been summarized in Table 4.8, emotions have been represented as *very low, low, moderate, high* and *very high* for the different contexts. The ratings were made on a scale of 0-100: 0-20 is very low, 21-40 is low, 41-60 is moderate, 61-80 is high and 81-100 is very high. The Cronbach's alpha for reliability was 0.767 and the findings for ANOVA were significant, as described in Table 4.7. The emotions were taken from Plutchik's Wheel of Emotions.

Table 4.7: ANOVA results for Feelings experienced in different scenarios

Contexts		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
	Between Groups	37.431	11	3.403	4.237	.000
Office	Within Groups	279.500	348	.803		
	Total	316.931	359			
	Between Groups	134.142	11	12.195	13.186	.000
School	Within Groups	321.833	348	.925		
	Total	455.975	359			
	Between Groups	125.031	11	11.366	13.323	.000
College	Within Groups	296.900	348	.853		
	Total	421.931	359			
	Between Groups	112.408	11	10.219	10.092	.000
Wedding	Within Groups	352.367	348	1.013		
	Total	464.775	359			
	Between Groups	106.422	11	9.675	11.726	.000
Park	Within Groups	287.133	348	.825		
	Total	393.556	359			
	Between Groups	49.356	11	4.487	5.618	.000
Commuting	Within Groups	277.933	348	.799		
	Total	327.289	359			

Table 4.8: Feelings experienced in different scenarios - word count content analysis

Emotions	Office	School	College	Wedding	Park	Commuting
JOY	Low	High	High	High	Moderate	Low
TRUST	Low	High	High	High	Low	Very low
OPTIMISM	Moderate	High	High	High	High	Low
LOVE	Low	High	High	High	Moderate	Low
FEAR	Moderate	Low	Low	Low	Moderate	Moderate
PENSIVE	Low	Low	Low	Very low	Low	Low
ANNOYANCE	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
AGGRESSION	Low	Low	Low	Low	Low	Moderate

4.3.5 Discussion of posit

On a scale of 0 (least) – 100 (maximum), 83% agreed more that dress/ attire/ clothing play an important role in projecting one's true self to the outside world (Figure 4.8). 57% agreed that textiles could be made more useful and helpful in socialization, while 40% agreed partially (Figure 4.9). This data shows the likeliness of respondents towards understanding that textiles could be important medium for communication and the data collected through the user study forms a base upon which heuristics for designing textile wearable can be initiate, as discussed in the next section.

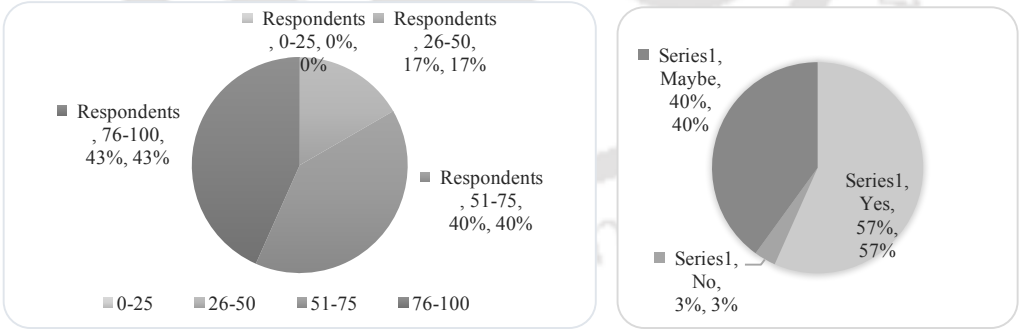


Figure 4.8: Response for whether Textiles express true self to the outside world;
Figure 4.9: Response for potential of textiles in facilitating socialisation

With finding as discussed in Tables 4.4-4.8, the study leads to evaluation of **Posit 2 – Significant levels of emotions, feelings, boundaries and comfort levels are experienced by users in a social space.**

4.4 Designing textile wearable prototypes for user evaluation – Inference model

The exploratory studies were conducted to understand how young respondents create invisible boundaries for sharing information and how different comfort levels are when interacting with different categories of people. Significant results implicate that these unexpressed boundaries and comfort levels could be expressed in certain known and unknown settings. Known settings and unknown settings could be college library, café, college premises, at office, commuting, airports, bus stops, parks, etc. Researchers hypothesized, that if textiles could communicate meanings and emotions subtly to the people around, in the above mentioned known and unknown settings, it could help in creating a decorum and increased understanding among individuals. It could assist users through non-verbal expression, empower users to express at times when words can't be used and thus make them socially intelligent through textiles which in turn leads to collective intelligence in the social space of the user. The exploratory studies led to conceptualization of prototype designs, for instance – how could emotions be expressed through textiles? How could boundaries/comfort levels be expressed by textiles? Could colours of textiles change to express different levels of boundaries/emotions/comfort levels? Could dynamic textures of textiles communicate boundaries/emotions/comfort levels? Such assumptions led to exploring possibilities of merging smart materials with textiles inspired from traditional craft practices of India.

The designing and exploration for prototype for subtle non-verbal communication has been discussed further. Design exploration of textile wearable was based on drawing inspirations from the handcrafted textiles of India and explore with available smart materials such as – conductive thread, LEDs, Conductive ink, etc. to develop a series of prototypes. The prototype is in the form of a scarf that can be worn on daily basis and smart functions could be used only when needed. The static textile crafts have been compared with the prototypes created through a detailed semantic analysis to understand the significance of constituting elements. Simultaneously methods of evaluation, formulation of tentative model for nonverbal communication and tentative hypotheses for research were formulated for examination in experimental phase.

As studied form literature about motifs of traditional textile of India, the perceptions of young respondents and the behavioral study, the socially intelligent textile was thus envisaged to be designed (Figure 4.10). This textile or prototypes as digital crafts will enable users in non-verbal expression of emotions and feelings as subtle indicators in their social space. The choice of expression solely remains with users, otherwise the electronic

elements remain neatly integrated as part of textile motifs/patterns. The socially intelligent textile encompasses attributes of Social Intelligence (Goleman, 2006), Emotions from Plutchik's Wheel and Proxemics (Sheppard, 1996) for denoting feelings and comfort levels in social space (Figure 4.11).

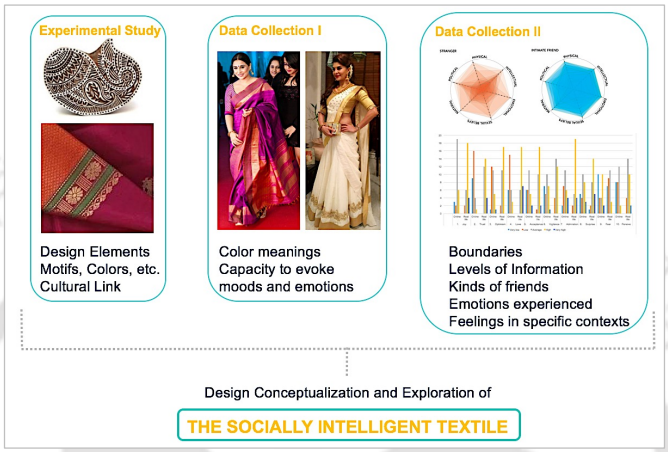


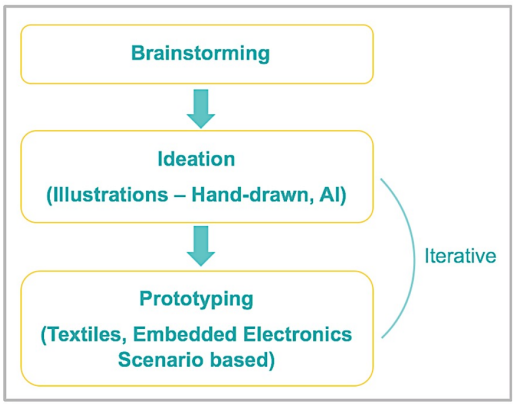
Figure 4.10: Inference model and implications in designing textile wearables

Figure 4.11: Attributes of Social Intelligence, Emotions and Proxemics (Sheppard, 1996)

4.4.1 User Centric Design process for designing prototypes

Designing included the steps mentioned in Figure 4.12 which were iterative. After brainstorming (Figure 4.13), illustrations and storyboarding based on use cases (Figure 4.14-4.19) was carried out. Explorations with paper and smart materials such as LEDs, conductive inks, conductive threads, Shape memory alloy, etc. took place. It was understood that creating prototypes for an entire sequence of storyboard (Figures 4.14-3.19) comprising several interactive textiles, such as – textiles changing colour, textiles changing pattern, textiles changing shape (growing and retracting), textiles becoming opaque and transparent, textiles measuring biometric of user, etc. was not possible while

prototyping. Thus, prototype exploration comprised of a single function at a time, such as – textile changing colour through LEDs, textiles changing patterns though thermo-chromic



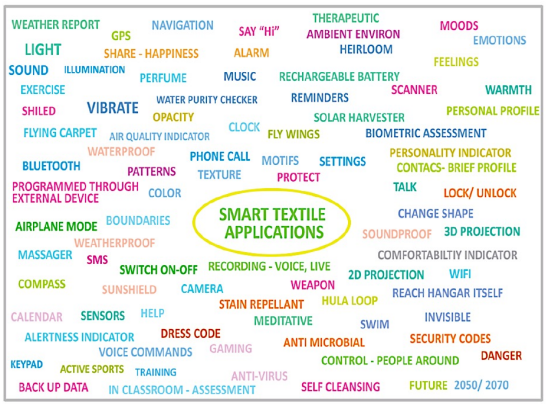


Figure 4.12: Steps of design process; **Figure 4.13:** Brainstorming

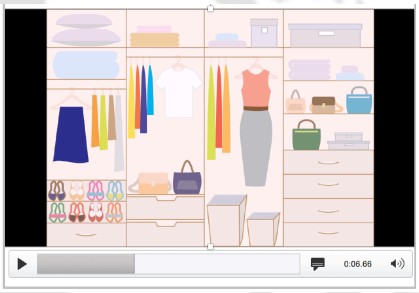
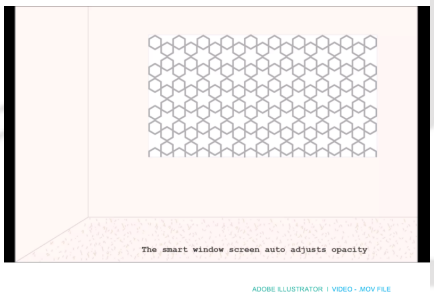


Figure 4.14: Storyboard 1 – User wakes up in the morning; **Figure 4.15:** Storyboard 2 – Interactive wardrobe (Annexure 13)



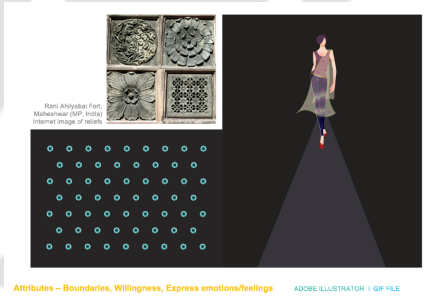


Figure 4.16: Storyboard 3- Screen that adjusts opacity and illumination; **Figure 4.17:** Storyboard 4 – Scarf with dynamic floral elements (Annexure 13)

Figure 4.18: Storyboard 5 – Traditional textile repository; **Figure 4.19:** Storyboard 6 – Textile wall displays for therapy and meditation (Annexure 13)

ink upon changing temperature, textile material opening and closing through an Arduino controlled unit, etc. It was intended to associate different functions to different prototypes (Figure 4.20) – LED based colour changing textile, textile that could open and closed based on proximity sensor, textile prints that could disappear upon application of heat using block printed thermos-chromic paint, a floral configuration that could open and close through Arduino motor to be used as miniaturized broch designs. Figure 4.20, column 1 represents a concept of LED embedded in *Phulkari* embroidery; column 2 represents a pleated sample which was intended to be embroider/painted/printed with opening and closing pleats; column three represents block printed sample in thermo-chromic ink which appear and disappear on heat application; and, fourth column represents a larger version of a miniature brooch which was intended to open-close upon a set of stimuli. Due to limitations owing to portability, power requirements, refined prototype development was not possible for few initial prototypes. Hence three different LED embedded textiles/scarves and a jacket were created based on designs derived from traditional craft practices as described further.

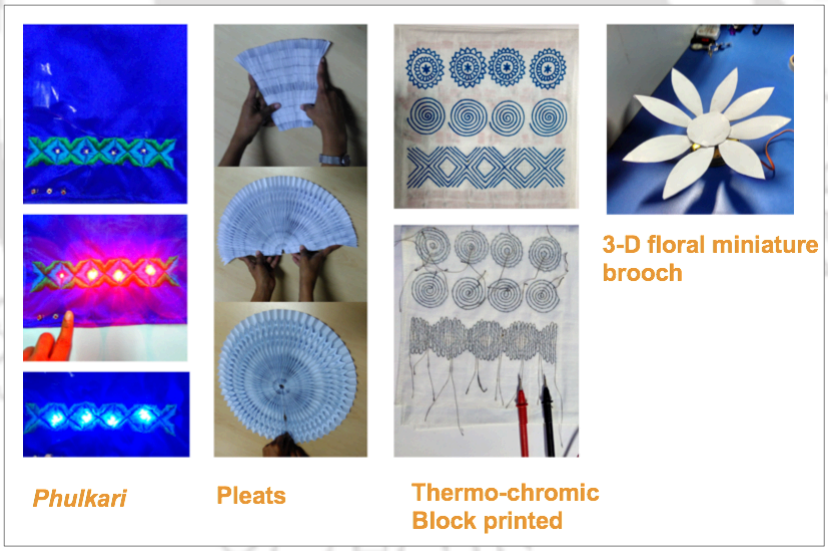


Figure 4.20: 3 forms with 3 different functions

First, a blue scarf with petal shaped embellishments and sequins, four micro RGB leads replace sequins in the bottom row inspired from *zardozi*. *Zardozi* (Sushanth, et al., n.d.) is the craft embroidering cloth with precious and semi-precious metal, stones, sequins, etc. as depicted in Figure 4.21. It was patronized by royal families of the Mughal era and was originally done with gold thread, *zari*. In recent times, bridal-wear are ornamented with *zardozi* work apart from other textile products and accessories. Based on the elements used and designs of *zardozi*, a scarf was embellished with petal shaped stones and sequins in the

shape of a six-petalled flower. This scarf called *Aster*, comprises of four micro RGB LED embedded floral designs in a row at the base controlled by three buttons to change colors as depicted in Figure 4.22. *Aster* is Prototype scarf 1.

Second prototype scarf is, *Iris*, black scarf with 9 LEDs embedded in three rows replacing traditional floral elements in a creeper motif border inspired from *Kantha* embroidery. *Kantha* is running stitch embroidery technique originating from West Bengal, India (Strandsofsilk, n.d.) as depicted in Figure 4.23. Running stitch covers the base and design of the fabric completely rendering a wavy texture to the fabric. Significance and symbolism is attached to motifs and colors used for the embroidery. Design elements for most traditional craft patterns are drawn from flora, fauna, local architectural styles, daily life and mythology (Veenu, et al., 2016) Based on running stitch floral designs, embroidery was made on a scarf with three rows of nine red, green and yellow LEDs embedded instead of floral motifs as depicted in Figure 4.24. LED colors are controlled with three buttons embroidered at the edge of the scarf.



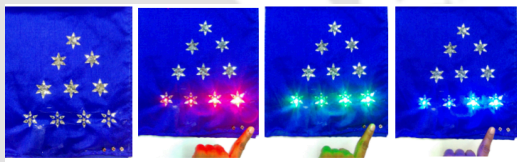


Figure 4.21: *Zardozi* embroidery; **Figure 4.22:** *Aster*, prototype scarf 1

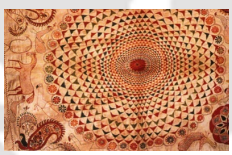
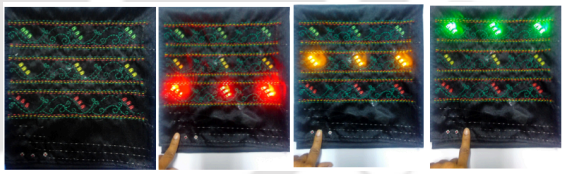




Figure 4.23: *Kantha* embroidery; **Figure 4.24:** *Iris*, prototype scarf 2



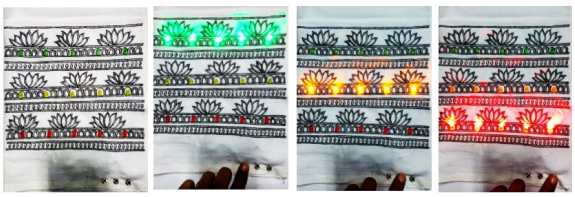


Figure 4.25: *Madhubani* Painting; **Figure 4.26:** *Nymphaea*, prototype scarf 3

Third prototype scarf is *Nymphaea*, *Madhubani* painted scarf with lotus motif, 5 LEDs placed in three rows. *Madhubani* paintings originated in Bihar (Gambhir, n.d.) and were made on mud painted walls and floors (Figure 4.25). Different designs are made according to festivals, occasions or prayers. Although they were made with vegetable colors now synthetic colors are used to decorate walls, textiles, lifestyle products and accessories. It is

identified by prominent black outlines for two-dimensional artworks of design elements which may or may not be filled with colors. Based on these paintings, *Nympahea* was designed (Figure 4.26) which has rows of the auspicious lotus motif with five rows of red, yellow and green LEDs controlled by three buttons at the base.

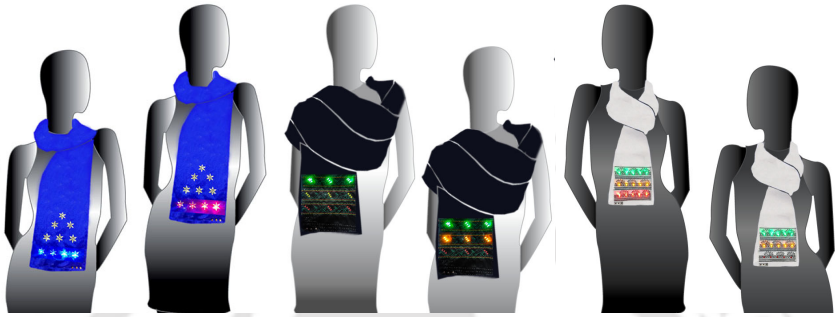


Figure 4.27: Prototype scarves rendered on mannequin

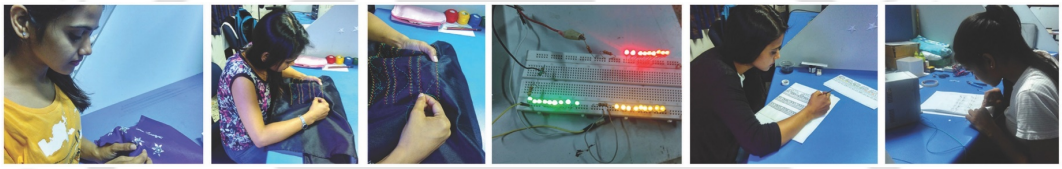


Figure 4.28: Prototyping the three scarves

All LEDs were connected with conductive thread, controlled by three buttons at the edge of the scarf and powered by 3.2V Lipoly battery at the back of the fabric that ensured portability and recharge-ability of the scarves. Figure 4.27 depicts the scarves rendered on a mannequin. Prototype scarf 1, *Aster,* was user for preliminary experiment prior to first experiment; and, Prototype scarves 1, 2 and 3, *Aster, Iris* and *Nymphaea,* were used for first experimental evaluation which led to testing and validation of the hypotheses and posited theoretical model for non-verbal communication (NVC) through textile wearables. Figure 4.28 depicts designing and prototyping of the three scarves.

A scarf was designed as a prototype because as studied in literature, most of the LED textiles by popular design studios, etc. (Figure 4.29) were meant of high-end fashion, i.e., couture wear and lacked in applicability as a daily lifestyle product particularly with respect to the young female users in India, the chosen demographic to conduct user evaluation. Scarf was practical, portable, easy to carry, weighed less, hassle free. Also, the scarves designed can be used to change colours, visual cues only when needed and not all the time. The LEDs are neatly embedded and merged as part of textile motif as a static textile would appear and change colours/ visual cues to transmit meanings as a dynamic textile. [Please refer Annexure 11 for circuit diagrams and Annexure 12 for prototype images and renderings].

Figure 4.29: LED textiles by Cutecircuit, Philips Bubelle emotion sensing dress, Pankaj and Nidhi Wills India Lifestyle 2012 collection *Geometrica*

Since a scarf could be used by female respondents only, a traditional jacket (*bundi*) was also designed which could be used by both male and female respondents. For a comparative evaluation in Experiment 2, two versions of the same jacket were designed – static (Figure 4.30- 4.31) and dynamic (Figure 4.32). The jacket is a traditional *bundi* stitched of poly dupion fabric with hand done embroidery in running stitch with pearls attached along the border. The dynamic jacket has an LED strip attached underneath which can be controlled by a wireless remote control. The dynamic LED jacket is Prototype 4 used as tool for experimental study 2 for hypotheses testing.

Figure 4.30: Static hand stitched *bundi* with close up of embroidery along border

The role of users is depicted in Figure 4.10, where the purpose of designing prototype is being derived from the users to indicate non-verbal expression – emotions, feelings, boundaries and comfort levels. The design development was an exploratory process where technological intervention of handmade crafts has been carried out and then responses has been gathered to iterate the prototype (the jacket designed) and the experimental set up (testing hypotheses 2,3). The users initiated the design process, designs were prototyped and tested with users, a different prototype was designed and tested with users again – this UCD process has been summarised in the design heuristic framework, Figure 6.1.

Figure 4.31: Model wearing static and dynamic jacket in cafeteria

Figure 4.32: Model wearing dynamic jacket – colors being controlled by a wireless remote

4.4.2 Semantic Analysis of static and dynamic crafts designed

According to Daniel Chandler (2002), *Sign* is anything that communicates a meaning and itself is not definitive of something particular; *Significance* is the meaning conveyed by a sign in a particular context; *Denotation* describes the definitional, literal, obvious or common-sense meaning of a sign; *Connotation* refers to the socio-cultural and 'personal' associations (ideological, emotional, etc.) of the *sign*; and, *Metaphor* involves one signified acting as a signifier referring to a different signified. Where, *Signifier* is *the concept of the sign,* while, *signified* is *the material or physical form or the meaning* understood by the *signifier*.

In the case of present research, a sematic analysis has been conducted to understand the similarities and differences between the static and dynamic prototypes developed. Figure 4.33 represents traditional static textile craft motifs (3 internet images) corresponding to *Aster, Iris* and *Nymphaea*, the scarves designed and the comparative semantic analysis has been discussed in Table 4.9. Figure 4.34 depicts the schema followed for comparing signs, significance, denotation, connotation and metaphorical meanings of static and dynamic textiles.

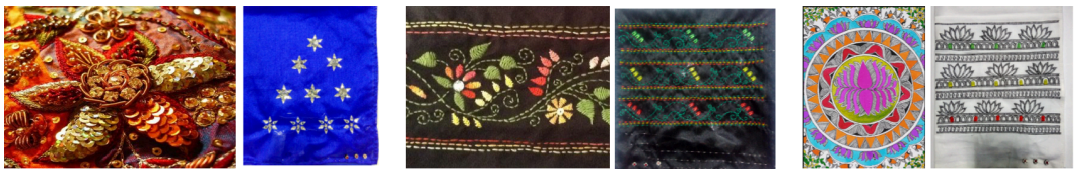


Figure 4.33: *Zardozi-Aster, Kantha-Iris* and *Madhubani-Nymphaea*

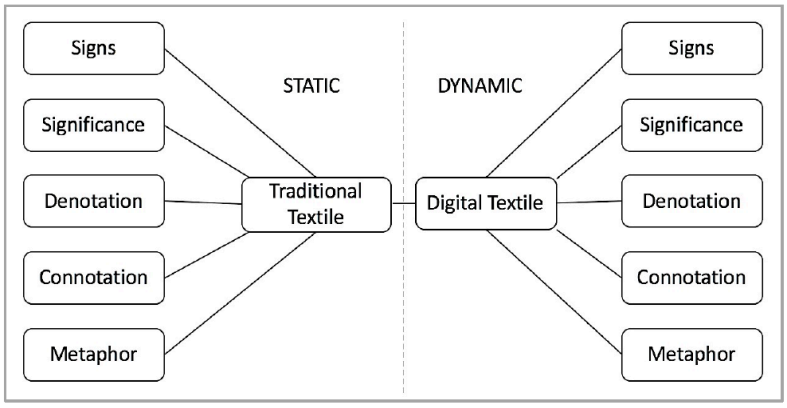


Figure 4.34: Comparative semantic analysis schema

The *signs*, i.e. design elements are similar in both the cases (Table 4.9). But, the *significance* of *dynamic* crafts differs from *static* craft. The static craft motifs and colors carry the cultural meanings and relevance to a particular occasion. However, the *dynamicity* of *digital* craft can enable several meanings in different contexts; such as, indicating moods, emotions, feelings, etc. as in case of experimentation in present research. The *denotative* elements are the *same* as *signs* for static crafts; but due to integration of embedded electronics, the denotative elements of *dynamic* crafts differ from the *static* crafts. The connotative meaning in case of static crafts from Figure 4.34, the *creepers*, *flowers* and *lotus* symbolize prosperity, growth, abundance and are worn for festivals, wedding and several other occasions to bring upon the wearer, these meanings of the motifs being worn. However, in case of dynamic crafts, there is addition to the meanings from that of the motifs of a static craft. The dynamic craft is capable of communicating non-verbal messages through its visual cues, in case of present research, and, the meanings that the dynamic visual cues could mean may be different in different experimental contexts and cultural scenarios. An example of metaphorical meanings of colors has been mentioned in Table 4.9, where *red, green, yellow* carry cultural and ritualistic significance for the occasions they are worn, but, dynamic crafts through their visual cues represent not only the above-said meanings but also convey other non-verbal signals required to be expressed by the wearer, if needed.

Table 4.9: Comparative semantic analysis of static and digitised textile craft

Semantic Attributes	**Traditional Textile**	**Digital Textile**
Signs	Design elements of motifs – Color, Shapes	Design elements of motifs – Color, Shapes
Significance	Static Aesthetics, Cultural connotations, Trends	Dynamic – Colors, Motifs Aesthetics with Intelligence, Trends
Denotation	Design elements of motifs – Color, Shapes	Electronics embedded as part of design elements, LEDs, Conductive thread, etc.
Connotation	Significance of motifs/colors for a particular occasion – Royalty – authority – tiger/ elephant Wedding – auspiciousness – lotus, parrots, elephant Celebration – festivity – creepers, florals, conches Occasion – peace – *rudraksha*, creepers Creepers – Spring, Life, freshness, vitality Lotus – Prosperity, Purity, Auspicious, Religious	Apart from *static* meanings, Significance of visual cues for functions, e.g. non-verbal communication; If applied to other scenarios such as geriatric, special needs, etc. a part of daily lifestyle and not just specific occasion IOT, AR, VR, AI
Metaphor	Red – Royal, Wedding, Love, Hatred Green – Purity, Prosperity, Fertility Yellow – Auspicious, Religious, Sun, Vitality	Red – boundaries, comfort level, willingness – Degree 1 Green – boundaries, comfort level, willingness – Degree 2 Yellow – boundaries, comfort level, willingness – Degree 3

4.5 Tentative hypotheses and NVC model proposition

Three tentative hypotheses proposed at this stage are – (i) Traditionally crafted textile wearables evoke positive emotions strongly in users than negative emotions; (ii) Digital textiles enable users to significantly express emotions in their social space than static textiles; (iii) Digital textiles enable users to significantly express feelings in their social space than static textiles.

The literature study led to finding few gaps that were to be addressed through the research questions and studies conducted, Table 2.1, p.35-36. The hypotheses emerged out of research question 4 - Are there possibilities of enhancing self-expression and non-verbal communication through digital textiles in the social space, if so how can they be captured and quantified? The two hypotheses being tested are - Digital textiles enable users to significantly express (a) emotions and (b) feelings in their social space than static textiles.

The hypotheses try to capture and quantify the expression and communication of emotions and feelings, under the large umbrella of non-verbal communication, through digital textiles as compared to a static textile. Emotions and feelings pertaining to textiles have been a keyword since the initial phase of research.

Questions discussed in Section 4.4 before designing prototypes were – "How could emotions be expressed through textiles? How could boundaries/comfort levels be expressed by textiles? Could colours of textiles change to express different levels of boundaries/emotions/comfort levels? Could dynamic textures of textiles communicate boundaries/emotions/comfort levels?"

The tentative hypothesis 2 is derived from the first question (from paragraph above). The tentative hypothesis 3 is derived from a combination of the remaining three questions. The 7 feelings evaluated by tentative hypothesis 3 - *I am relaxed, Leave me alone, I am waiting, I am thinking deeply, I am ok to talk, I am angry, I am in a good mood* – indirectly intend to represent levels of boundaries and comfort levels of the participants though visual cues, i.e. changing LED colors. While the tentative hypothesis 1 emerges out of findings of sub-section 4.2.2, Figures 4.3-4.6. Sub-section 4.2.2 reports that traditional textiles evoke more positive emotions than negative emotions, hence hypothesis 1 intends to compare the *emotions evoked* by static and dynamic textiles.

A tentative theoretical model for non-verbal communication with prototyped digital textile crafts (Figure 4.35) is also posed here which will be iterated upon and tested in subsequent stages (Please refer Annexure 6l for proposition and refinement of NVC model). The model as inferred from exploratory studies 1 and 2 suggests that attributes of *Social Intelligence* and *Positive emotions* are significantly and positively correlated with technology acceptance of prototyped digital textile crafts leading to high perceived usefulness and perceived ease of use among users. Factors of *Boundaries, Comfort Levels* and *Emotions experienced* in different social contexts contribute to social intelligence (Figure 4.11). A textile capable of expressing boundaries, comfort levels and emotions subtly in specific contexts imparts wearer with intelligence in their social space. The expression in the case of the prototypes designed (Figure 4.22, 4.24, 4.26 and 4.31) is facilitated through visual cues – where colors with their meaning convey certain attributes by the wearer to the surrounding.

Preliminary study reported in Annexure figure 6e was conducted prior to Experimental study 1 and 2. The tentative NVC model was a result of preliminary study Annexure Figure 6e. The NVC model took shape in 3 stages - Figure 4.10, Annexure figure 6d and Annexure figure 6e. The model in Figure 4.35 intends to examine the effect of emotions, social

intelligence and aesthetics on levels of technological acceptance among participants – Do *Emotions*, *Aesthetics* and factors measuring *Social Intelligence* have an impact on TAM? This has been done to understand the role of different variables of the experiments in acceptance of the prototypes designed in context of non-verbal self-expression.

During the exploratory phase, attitude formation was also a part of the two studies conducted, so opinion about personality traits had to be indicated by the participants. However, later the focus moved to emotions and feelings towards the experimental studies, among all the possibilities that exploratory studies presented authors with. Few personality traits were synonymous with attributes of aesthetics (Blijlevens, et al, 2017) so most used terms were taken for evaluation of prototype scarves, effect of aesthetics on technology acceptance. Emotions and non-verbal expression are keywords in focus for present research which have been together studied and analyzed in relation to TAM.

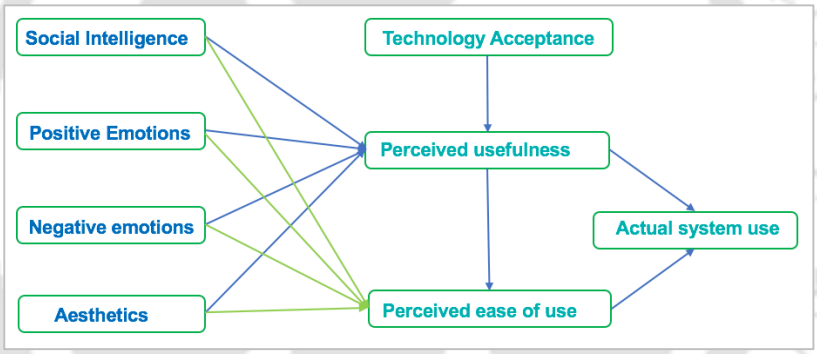


Figure 4.35: Tentative theoretical model for non-verbal communication with digital textile crafts

Chapter Summary: *This chapter discusses the findings of Exploratory Study 1 (Perceptions of young users about traditional textiles) and Exploratory Study 2 (Behaviour of young users in social space in terms of boundaries, comfort levels and emotions). The implications of these findings in designing wearables and designing of digitally crafted textile wearables has also been reported in this chapter. User evaluation of the textile prototypes via two experiments for testing three hypotheses and the theoretical model for non-verbal communication with digital crafts, has been reported in the next chapter.*

Chapter 5

Experimental studies for evaluation of Digital textile crafts designed

This chapter explains the results obtained from analysis of the two experimental studies conducted with three LED embedded scarves and a dynamic LED jacket. The theoretical model for non-verbal communication with textile wearables and one hypothesis has been validated by Experimental study 1 and the two other hypotheses have been validated by Experimental study 2.

5.1 Introduction

The following subsections will discuss findings of the two experimental studies. Experimental study 1 was conducted with 3 LED embedded scarves and 60 respondents for the same factors as preliminary Experiment as reported in Annexure 6. The first experimental study is being replicated three times with the three prototypes which lead to validation of the theoretical model for non-verbal communication with textile wearables. A new measure for measuring non-verbal communication has also been posited and validated by Experimental study 1 via Principal Component Analysis. Hypotheses 1 and 3 posits were evaluated through Experiment 1. Experimental study 2 was conducted with a static and dynamic LED jacket for testing hypotheses 2 and 3 positioned in this research.

5.2 Analysis of Experimental Study 1

Experimental study 2 was a replicated experimental study conducted with 60 female respondents between the age group 18-32 years studying at graduate/post-graduate level. 60 respondents took part in an interactive session of groups 2-3, where they were asked to imagine being in any one or more of the scenarios, such as travelling alone in a metro, bus stops, college library, strolling in a park, etc. The users then communicated meanings through colors of *Aster, Iris* and *Nymphaea,* the prototype scarves 1, 2 and 3 respectively. The study captured the experience and functionality of *Aster, Iris* and *Nymphaea* when colors change to express certain additional meanings, such as red glow could mean *stop, do not approach, please leave, I am not interested, I am angry, I disagree,* etc. Blue/Yellow glow could mean *I am slightly approachable, you could stay but not very long, I am slightly interested, I am not very pleased, I slightly disagree,* etc. While a Green

glow could mean *you are welcome, you may approach, you may stay, I am interested, I am pleased, I agree,* etc.

7 variables measuring non-verbal communication on a 5-point semantic differential scale, 5 variables measuring positive emotions on a 5-point Likert scale, 5 variables measuring negative emotions on a 5-point Likert scale, 10 variables of System Usability Scale and 12 variables of perceived usefulness and perceived ease of use from Technology Acceptance Model were captured on a questionnaire for the three scarves. The data was non-parametric, as Kolmogorov Smirnov and Shapiro–Wilk tests were significant. So, Spearman's Correlation Analysis was used for evaluating correlational significance of the NVC model and for hypotheses testing. Principal Component Analysis was used for determining variables for evaluation of social intelligence/ non-verbal communication with textile wearables, as a replicated test with three scarves (Tables 5.5-5.7). Friedman's ANOVA for analyzing emotions has been used.

Spearman's Correlation is a non-parametric version of Pearson's correlation which is used for parametric data. The correlation coefficient measures the direction (positive or negative) and strength between the variables (Kothari, 2004 and Field, 2009). Principal Component Analysis is a dimension reduction tool which reduces large amount of data into smaller sets based on strong patterns in dataset (Kothari, 2004 and Field, 2009). Friedmans' ANOVA is a non-parametric version of ANOVA (used for parametric data) for analysis of variance based on mean comparison (Field, 2009).

Usability assessment of *Aster, Iris* and *Nymphaea* based on System Usability Scale (SUS) revealed positive results – SUS score for *Aster*=72.54; *Iris*=77.92 and *Nymphaea*=74.46. The results of SUS score along with similarity revealed by correlation values of $\mathbf{r}_s$ in Figures 5.1-5.3 and Table 5.4 revealed the preference of respondents were similar for using either of the scarves for the purpose of non-verbal expression.

5.2.1 Testing Hypothesis 1

Experimental study Tables 5.2-5.3 depict Friedman's ANOVA and Wilcoxon signed rank test for mean values of positive emotions compared to the mean values of negative emotions for each of the three scarves. Significance p=0.00 indicates positive emotions were evoked significantly different than the negative emotions. Table 5.1, Descriptive statistics of emotions evoked based on values of mean, standard deviation and mode, reports that the 5 positive emotions are evoked much higher than the negative emotions for the three scarves among the 60 respondents. With the results depicted in

Tables 5.1-5.3, the Null hypotheses is rejected and the alternate hypothesis is accepted as stated below.

$H1_a$ – Traditionally crafted textile wearables evoke positive emotions strongly in users than negative emotions.

$H1_0$ – Traditionally crafted textile wearables do not evoke positive emotions strongly in users than negative emotions.

Table 5.1: Descriptive statistics of emotions evoked Experimental study 2 – *Aster, Iris* and *Nymphaea* (Scarves 1,2 and 3 respectively)

Scarf	Happiness	Optimistic	Awesome	Interesting	Admirable	Sad	Pessimistic	Boring	Annoying	Disgusting
MEAN										
1	3.98	3.81	3.61	4.1	3.85	1.25	1.46	1.33	1.41	1.18
2	3.95	3.75	3.68	4.05	4.03	1.52	1.55	1.35	1.35	1.32
3	4.06	3.96	3.88	4.06	4.1	1.43	1.35	1.45	1.28	1.3
STDEV										
1	0.96	0.89	1.01	0.96	0.89	0.63	0.94	0.68	0.81	0.65
2	1.05	1.09	1.11	0.89	0.92	0.91	0.89	0.79	0.71	0.87
3	0.89	1.1	0.99	0.82	0.85	0.72	0.75	0.83	0.69	0.86
MODE										
1	5	4	4	4	4	1	1	1	1	1
2	5	4	4	5	4	1	1	1	1	1
3	5	5	4	4	4	1	1	1	1	1

Table 5.2: Friedman's Test - Statistics

	Values
N	60
Chi-Square	243.682
df	5
Asymp. Sig.	**.000**

Table 5.3: Wilcoxon Signed Ranks Test - Statistics

	Mean values of positive emotions with negative emotions for *Aster*	**Mean values of positive emotions with negative emotions for *Iris***	**Mean values of positive emotions with negative emotions for *Nymphaea***
Z	-6.674[b]	-6.688[b]	-6.709[b]
Asymp. Sig. (2-tailed)	**.000**	**.000**	**.000**
b. Based on positive ranks.			

5.2.2 Validation of posited model for non-verbal communication through textile wearables

The model in Figure 4.35 intends to examine the effect of emotions, social intelligence and aesthetics on levels of technological acceptance among participants – Does Emotions,

Aesthetics and SI have an impact on TAM? So after evaluation of posits 3-5, p.84 and 85, it was found that aesthetics, positive emotions and SI were positively correlated with TAM and Negative emotions were negatively correlated with TAM, as reported below.

Cronbach's α for reliability for the NVC model ranged between .767 and .883 for the three scarves. To cite results of one wearable scarf *Aster,* as mentioned in Figure 5.1 and Table 5.4, Spearman's Correlation results for *Aster* revealed that –

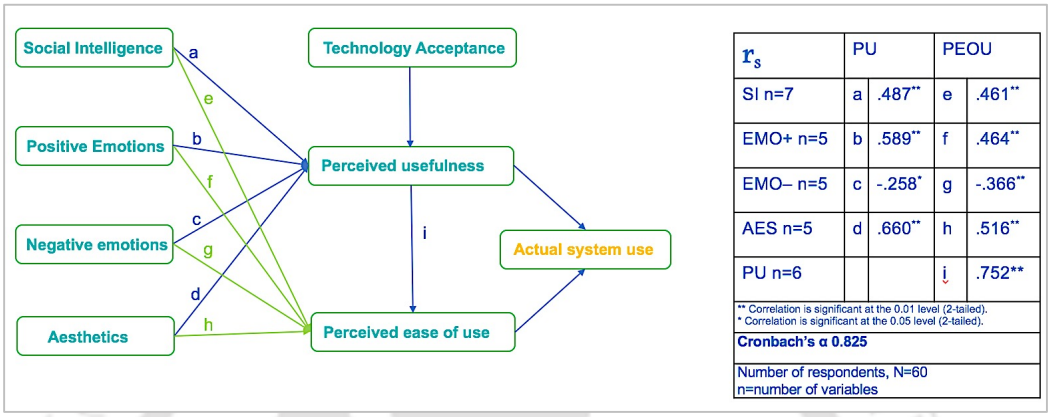
Positive emotions were positively correlated with perceived usefulness and perceived ease of use $\mathbf{r}_s$ = 0.589 and 0.464 respectively, significant at p<0.01 for a two-tailed test. Negative emotions were negatively correlated with perceived usefulness and perceived ease of use $\mathbf{r}_s$ = -0.258 significant at p<0.05 for a two-tailed test and $\mathbf{r}_s$ = -0.366 significant at p<0.01 for a two-tailed test. **Posit 3 thus evaluated states that Traditionally crafted wearables strongly influence positive and negative emotions leading to high perceived usefulness and perceived ease of use.**

Aesthetic attributes were positively correlated with perceived usefulness and perceived ease of use $\mathbf{r}_s$ = 0.660 and 0.516 respectively, significant at p<0.01 for a two-tailed test. **Posit 4 thus evaluated states that Aesthetics has significant effect on technology acceptance - perceived usefulness and perceived ease of use for traditionally crafted wearables**

Social Intelligence was positively correlated with perceived usefulness and perceived ease of use $\mathbf{r}_s$ = 0.487 and 0.461 respectively, significant at p<0.01 for a two-tailed test. **Posit 5 thus evaluated states that Traditionally crafted wearables significantly enhance non-verbal expression among users in a given social space leading to high perceived usefulness and perceived ease of use.**

Similarly, Strong correlations were indicated for *Iris* and *Nymphaea* for social intelligence, positive emotions, aesthetic attributes, perceived usefulness and perceived ease of use, as described in Figures 5.1-5.3 and summarized in Table 5.4. Negative emotions were not significantly correlated with perceived usefulness and perceived ease of use for *Iris*. Negative emotions were not significantly correlated with perceived ease of use for *Nymphaea*. Perceived usefulness and perceived ease of use were positively correlated for

Aster, Iris and *Nymphaea* - $\mathbf{r}_s$ = 0.752, 0.71 and 0.651 respectively, significant at p<0.01 for a two-tailed test, which leads to actual system usage according to Technology Acceptance Model.



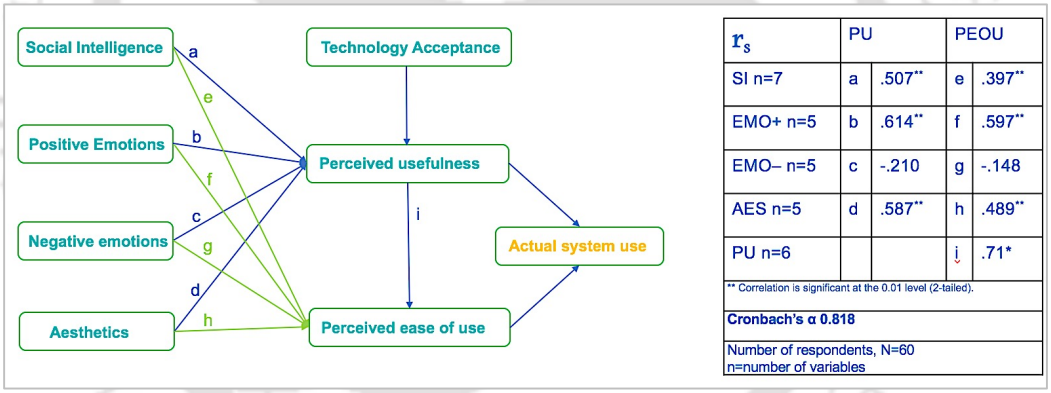
r_s	PU		PEOU	
SI n=7	a	.487**	e	.461**
EMO+ n=5	b	.589**	f	.464**
EMO– n=5	c	-.258*	g	-.366**
AES n=5	d	.660**	h	.516**
PU n=6			i	.752**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Cronbach's α 0.825

Number of respondents, N=60
n=number of variables

Figure 5.1: Posited NVC model for *Aster*



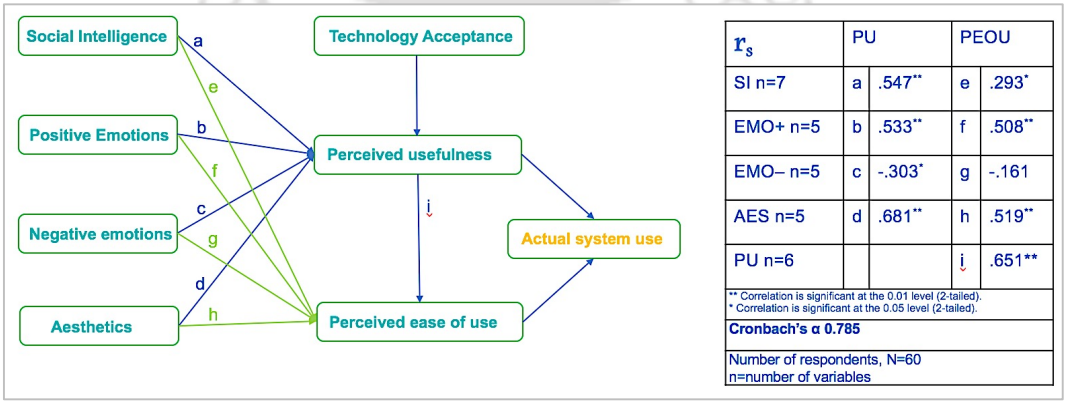
r_s	PU		PEOU	
SI n=7	a	.507**	e	.397**
EMO+ n=5	b	.614**	f	.597**
EMO– n=5	c	-.210	g	-.148
AES n=5	d	.587**	h	.489**
PU n=6			i	.71*

** Correlation is significant at the 0.01 level (2-tailed).

Cronbach's α 0.818

Number of respondents, N=60
n=number of variables

Figure 5.2: Posited NVC model for *Iris*



r_s	PU		PEOU	
SI n=7	a	.547**	e	.293*
EMO+ n=5	b	.533**	f	.508**
EMO– n=5	c	-.303*	g	-.161
AES n=5	d	.681**	h	.519**
PU n=6			i	.651**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Cronbach's α 0.785

Number of respondents, N=60
n=number of variables

Figure 5.3: Posited NVC model for *Nymphaea*

Table 5.4: Summary of evaluation of Posited NVC model for *Aster, Iris* and *Nymphaea*

Scarf	Factor	PU	PEOU
Aster	SI	.487**	.461**
Iris	SI	.507**	.397**
Nymphaea	SI	.547**	.293*
Aster	EMO+	.589**	.464**
Iris	EMO+	.614**	.597**
Nymphaea	EMO+	.533**	.508**
Aster	EMO–	-.258*	-.366**
Iris	EMO–	-.210	-.148
Nymphaea	EMO–	-.303*	-.161
Aster	AES	.660**	.516**
Iris	AES	.587**	.489**
Nymphaea	AES	.681**	.519**
Aster	PU	1	.752**
Iris	PU	1	.71**
Nymphaea	PU	1	.651**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Cronbach's α 0.785 to 0.825

5.2.3 Measurement of Non-verbal communication with 7 factors validated through Principal Component Analysis

Principal component analysis for 7 variables measuring NVC with respect to Perceived usefulness and Perceived ease of use was carried out for *Aster, Iris* and *Nymphaea*. KMO test for sampling adequacy – 0.799 for *Aster*; 0.880 *Iris*; and, 0.933 for *Nymphaea*. Bartlett's Test for component correlation was significant, p=0.00. 2 components were extracted on the basis of Eigen values. The 7 variables of NVC loaded together. Table 5.5-5.7 depicts NVC with respect to perceived usefulness and perceived ease of use for *Aster*, *Iris* and *Nymphaea*. The seven questions asked to the respondents rated on a 5-point semantic differential scale (1=disagree, 5=agree) were - (i) Do you think visual cues create a better understanding among people around? (ii) Do you think feelings can be expressed non-verbally through visual cues? (iii) Do you think feelings can be understood non-verbally through visual cues? (iv) Do you think interaction with visual cues

could be smooth and socially dignified? (v) Do you think personality can be expressed through visual cues effectively? (vi) Do you think visual cues could influence the outcome of people's behavior? (vii) Do you think colours can be used as cues to communicate and interpret feelings or boundaries? Please refer Annexure 7 for the questionnaire used in the Experimental Study 2.

Table 5.5: Pattern Matrix for *Aster*

Pattern Matrix SI-PU-ASTER			**Pattern Matrix SI-PEOU-ASTER**		
	Component			Component	
	1	2		1	2
SI1	.032	.712	SI1	.076	.671
SI2	.086	.696	SI2	-.052	.778
SI3	.328	.635	SI3	.168	.759
SI4	-.044	.612	SI4	.092	.501
SI5	-.112	.761	SI5	-.181	.786
SI6	.317	.492	SI6	.002	.698
SI7	-.034	.640	SI7	.108	.543
PU1	.898	-.044	PE1	.881	-.090
PU2	.951	-.128	PE2	.756	.119
PU3	.848	.066	PE3	.759	.158
PU4	.900	.029	PE4	.793	.091
PU5	.852	.017	PE5	.817	.111
PU6	.723	.156	PE6	.971	-.164

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 5 iterations.

Table 5.6: Pattern Matrix for *Iris*

Pattern Matrix SI-PU-IRIS			**Pattern Matrix SI-PEOU-IRIS**		
	Component			Component	
	1	2		1	2
SI1	.113	.561	SI1	.615	-.077
SI2	.106	.733	SI2	.834	.042
SI3	.005	.832	SI3	.807	-.054
SI4	-.090	.818	SI4	.802	.105
SI5	-.043	.799	SI5	.749	-.017
SI6	-.050	.779	SI6	.743	.025
SI7	.137	.655	SI7	.689	-.109
PU1	1.009	-.181	PE1	-.145	-.827
PU2	.910	-.004	PE2	.243	-.754
PU3	.891	.059	PE3	.074	-.869
PU4	.814	.156	PE4	.068	-.874
PU5	.906	.031	PE5	.184	-.777
PU6	.772	.171	PE6	-.143	-.891

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 7 iterations.

Table 5.7: Pattern Matrix for *Nymphaea*

Pattern Matrix SI-PU-NYMPHAEA			Pattern Matrix SI-PEOU-NYMPHAEA		
	Component			Component	
	1	2		1	2
SI1	.152	.705	SI1	-.069	.822
SI2	-.013	.793	SI2	-.108	.812
SI3	.220	.755	SI3	.089	.876
SI4	-.248	.924	SI4	-.029	.746
SI5	.246	.612	SI5	.064	.758
SI6	.166	.679	SI6	.055	.765
SI7	.037	.658	SI7	.061	.656
PU1	.920	-.026	PE1	.906	-.158
PU2	.968	-.011	PE2	.827	.133
PU3	.852	.125	PE3	.885	-.004
PU4	.905	.025	PE4	.905	.036
PU5	.733	.062	PE5	.864	.080
PU6	.878	-.008	PE6	.909	-.013

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 6 iterations.

5.3 Analysis of Experimental Study 2

The second Experimental study was conducted with 124 respondents between the age group 18-32 years studying in fashion design and fashion management courses at graduate and post-graduate level. The study captured response of a static traditional jacket to a dynamic LED jacket that could change 8 colors through a wireless remote control. Responses for 12 emotions evoked and 7 feelings expressed by respondents was captured on a questionnaire. Normality test Kolmogrov-Smirnov and Shapiro-Wilk were significant. The data was non-parametric in nature. When asked to opt for a method of expression of

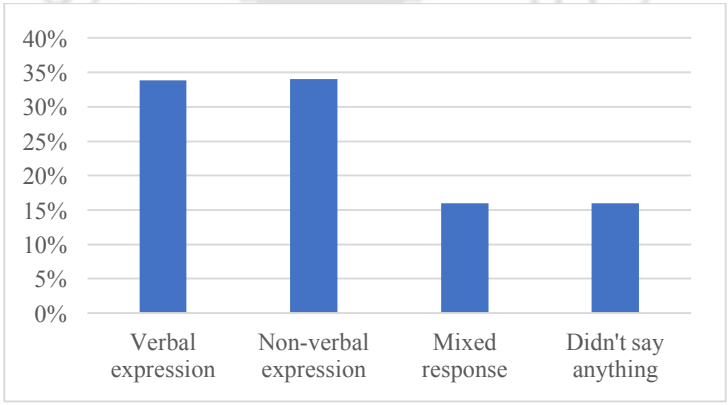


Figure 5.4: Preference for verbal or non-verbal expression by respondents

emotions and *feelings* between verbal and non-verbal – 34% opted for verbal expression, 34% opted for non-verbal expression, 16% provided a mixed response in descriptive section and 16% did not say anything (Figure 5.4). An example of verbal expression was the LED message tee and for non-verbal expression was the LED jacket that could convey meanings through visual cues. The results of hypothesis testing have been discussed in subsections further.

5.3.1 Findings on *Emotions evoked* and testing Hypothesis 2

12 emotions (6 positive, 6 negative) compared for Static Jacket and Dynamic Jacket, rated on a five point Likert scale (1=very low, 5=very high). 12 Emotions from the Plutchik's Wheel of Emotion are – *Happiness, Optimism, Awesomeness, Interesting, Admirable, Sadness, Pessimistic, Boring, Annoying, Disgusting, Angry* and *Surprised*. Users experienced and interacted with both the jackets before marking their response in the Questionnaire provided. Cronbach's Alpha for Reliability was 0.798. Friedmans' ANOVA for 12 emotions for Static jacket and average of 8 colors as dynamic jacket were significant (Table 5.8). So Post-hoc analysis Wilcoxon Signed Ranks Test was conducted for ratings of static jacket with each of the eight colors – Red, Green, Blue, Teal, Purple, Orange, Yellow and White (Table 5.9). Significant result was obtained for emotions evoked by the visual cues of the jacket with respect to the static jacket. Table 5.8 and 5.9 with p=0.00 for values of emotions evoked for static vs the dynamic jacket confirms the second hypothesis. Null hypothesis is rejected.

$H2_a$ - Digital textiles evoke emotions significantly in the social space of users than static textiles.

$H2_0$ - There is no significant difference between evoked by the static and dynamic textiles in the social space of users.

Table 5.8: Friedman's ANOVA for static with average of dynamic responses

Test Statistics[a]	
N	1488
Chi-Square	40.361
df	1
Asymp. Sig.	**.000**
a. Friedman Test	

Table 5.9: Post-hoc analysis for emotions evoked by static jacket with 8 colors of dynamic jacket

	Test Statistics[a]							
	Red - Emo Stat	Green - Emo Stat	Blue - Emo Stat	Teal - Emo Stat	Purple - Emo	Orange - Emo Stat	Yellow - Emo Stat	White - Emo Stat
Z	-3.608[b]	-3.206[b]	-4.044[b]	-4.236[b]	-3.761[b]	-5.950[b]	-6.074[b]	-4.503[b]
Asymp. Sig. (2-tailed)	**.000**	**.001**	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

According to descriptive mean table, Positive emotions were evoked higher than the negative emotions for both static and dynamic jacket similarly (Table 5.10). For indication for the vocabulary, according to mean values of colors with respect to 12 emotions, following are the most preferred or most-representative emotions. Negative emotions have been least preferred. The mean values are only above average for first preference, in the range of 3.22-3.8 (Table 5.11). For more accurate representations, larger sample size and gender based preferences need to be studied.

Table 5.10: Mean values of emotions evoked with respect to static and 8 colors of dynamic jacket

Emotion	Emo Stat	Red	Green	Blue	Teal	Purple	Orange	Yellow	White
Happiness	2.93	2.18	3.09	3.47	3.54	3.27	3.48	3.77	3.40
Optimism	3.38	2.23	3.21	3.3	3.38	3.18	3.27	3.66	3.63
Awesome	2.79	2.51	3.08	3.67	3.56	3.40	3.23	3.64	3.29
Interesting	3.08	2.78	3.23	3.62	3.61	3.42	3.38	3.55	3.22
Admirable	3.09	2.56	2.93	3.41	3.53	3.38	3.098	3.36	3.46
Sad	2.09	2.05	1.94	2.09	1.90	1.93	1.88	1.758	2.37
Pessimistic	2.15	2.68	2.26	2.20	2.01	2.11	2.06	1.87	2.05
Boring	2.48	2.09	2.10	1.82	1.81	1.92	2.06	2	2.25
Annoying	1.85	3.06	2.15	1.69	1.83	2.02	2.31	1.97	1.86
Disgusting	1.63	2.57	2.30	1.58	1.82	1.98	2.15	1.93	1.66
Angry	1.54	3.89	1.82	1.52	1.54	1.79	2.15	1.73	1.63
Surprised	2.37	2.91	2.86	2.86	2.95	2.93	3.26	3.18	2.69

Table 5.11: Most preferred three representations of colors with emotions (mean value in brackets)

Color	Emotion 1	Emotion 2	Emotion 3
Static	Optimism (3.38)	Admirable (3.09)	Interesting (3.08)
Red	Angry (3.8)	Annoying (3.06)	Surprised (2.9)
Green	Interesting (3.22)	Optimism (3.2)	Happiness (3.09)
Blue	Awesome (3.7)	Interesting (3.6)	Happiness (3.47)
Teal	Interesting (3.6)	Awesome (3.55)	Happiness (3.54)
Purple	Interesting (3.41)	Awesome (3.40)	Happiness (3.27)
Orange	Happiness (3.48)	Interesting (3.37)	Optimism (3.27)
Yellow	Happiness (3.77)	Optimism (3.66)	Awesome (3.63)
White	Optimism (3.62)	Admirable (3.46)	Happiness (3.4)

5.3.2 Findings on *Feelings expressed* and testing Hypothesis 3

7 Feelings were to be expressed by the static jacket and 8 colors of the dynamic jacket. Users experienced and interacted with both the jackets before marking their response in the Questionnaire provided. The users had to first rate the 8 colors of the LED jacket worn by the model at the cafeteria to identify which *feeling* was being expressed, as perceived by them. And in the next part, they had to imagine themselves sitting in the cafeteria (same scenario) and express the *feelings* listed through the 8 colors, as if they were expressing the *feelings* listed through the 8 given colors. The respondents also had to rate the level of these feelings being expressed by the static jacket. The Cronbach's Alpha for Reliability was 0.727.

Friedman's ANOVA for ratings for the 7 feelings of static jacket with mean values of Feelings as being expressed by the model in the photograph and Feelings as the users would express in the same setting were carried out, which yielded significant results (Table 5.12, 5.13). Post Hoc analysis (Wilcoxon Signed Ranks Test) for 7 feelings represented by static jacket with the 8 colors of dynamic jacket during photo elicitation (Table 5.14), depicts significant results for Red, Blue and white at $p<0.05$ and significant for Teal at $p<0.10$. 7 feelings represented by static jacket with the 8 colors of dynamic jacket as the participants would represent if they were in the same scenario as that of the cafeteria (Table 5.15), depicts significant results for Red, Blue, White and Yellow at $p<0.05$ and Teal at $p<0.10$. The results collectively prove that users felt that visual cues or colors of a dynamic jacket could be used to represent feelings in their social space, if required, in a given context than the static jacket. The null hypothesis is rejected.

$H3_a$ – Digital textiles enable users to significantly express feelings in their social space than static textiles.

$H3_0$ – There is no significant difference between feelings expressed by static and dynamic textiles.

Table 5.12: Friedman's ANOVA Feelings Expressed by static jacket and the model in the photograph as rated by respondents during photo elicitation

Test Statistics[a]	
N	875
Chi-Square	119.698
df	8
Asymp. Sig.	.000
a. Friedman Test	

Table 5.13: Friedman's ANOVA Feelings Expressed by static jacket and what the users would represent if in the same scenario

Test Statistics[a]	
N	874
Chi-Square	122.865
df	8
Asymp. Sig.	.000
a. Friedman Test	

Table 5.14: Post hoc analysis - Feelings Expressed by static jacket and the model in the photograph as rated by respondents during photo elicitation

Test Statistics[a]								
	Red1 - Static	**Green1 - Static**	**Blue1 - Static**	**Teal1 - Static**	**Purple1 - Static**	**Orange1 - Static**	**Yellow1 - Static**	**White1 - Static**
Z	-3.066[b]	-.582[c]	-3.334[c]	-1.582[c]	-.977[b]	-.139[b]	-.590[c]	-5.363[c]
Asymp. Sig. (2-tailed)	**.002**	.561	**.001**	**.114**	.329	.890	.555	**.000**
a. Wilcoxon Signed Ranks Test								

Table 5.15: Post hoc analysis for Feelings Expressed by static jacket and what the users would represent if in the same scenario

Test Statistics[a]								
	Red2 - Static	**Green2 - Static**	**Blue2 - Static**	**Teal2 - Static**	**Purple2 - Static**	**Orange2 - Static**	**Yellow2 - Static**	**White2 - Static**
Z	-2.804[b]	-1.273[c]	-4.508[c]	-1.521[c]	-.964[c]	-.529[c]	-1.886[c]	-4.990[c]
Asymp. Sig. (2-tailed)	**.005**	.203	**.000**	**.128**	.335	.597	**.059**	**.000**
a. Wilcoxon Signed Ranks Test b. Based on positive ranks. c. Based on negative ranks.								

For indication for the vocabulary, according to mean values of colors with respect to the 7 feelings, following are the most preferred or most-representative colors for the 7 feelings. The mean values are only above average for first preference, in the range of 4.3-2.59. For more accurate representations, larger sample size and gender based preferences need to be studied. Table 5.16 depicts all responses of photo elicitation of what the users perceived the model in the photograph expressed the feelings through colors. While Table 5.17 depicts the first three most preferred connotations of Table 5.16. Table 5.18 represents all responses for feelings that the respondents would like to express if in the same social context as that of the cafeteria. Table 5.19 represents the three most preferred responses of Table 5.18. According to Tables 5.16-5.19, the Static jacket being *white* represents *Optimism, Admiration* and arouses *Interest* among participants. The *Red* color of dynamic jacket represents Anger, Annoyance and Surprise; Green represents Interest, Optimism and

Happiness; Blue and Purple represent Awesomeness, Interest and Happiness; Orange represents Happiness, Interest and Optimism, Yellow represents Happiness, Optimism and Awesomeness; while, White represents Optimism, Admiration and Happiness. The evaluation also re-confirms strong associations of the colors with positive connotations and emotional expression. Such color connotations could come useful in designing a vocabulary for non-verbal expression using visual cues, such as colors that could mean or represent the same meanings to a culturally distinct population.

Table 5.16: Representing feelings through colors as observed by the respondents for the model in the cafeteria depicted in the picture – all responses

Feelings	Static	Red1	Green1	Blue1	Teal1	Purple1	Orange1	Yellow1	White1
I am relaxed	3.83	1.57	3.24	3.80	3.82	2.96	2.88	3.35	4.19
Leave me alone	2.28	3.95	2.5	2.17	2.22	2.64	2.71	2.37	2.44
I am waiting	2.54	2.41	3.26	3.42	3.33	3.24	3.05	3.29	3.27
I am thinking deeply	3.32	2.59	2.77	3.29	3.05	2.68	2.73	2.59	3.59
I am ok to talk	3.24	1.85	3.45	3.39	3.43	3.13	3.07	3.33	3.53
I am angry	1.73	4.36	2.23	2.02	1.91	2.33	2.81	2.26	1.72
I am in a good mood	3.57	1.90	3.38	3.65	3.43	3.09	3.15	3.57	3.84

Table 5.17: Representing feelings through colors as observed by the respondents for the model in the cafeteria depicted in the picture – three most preferred response (Mean values in brackets)

Color	Feeling 1	Feeling 2	Feeling 3
Static	I am relaxed (3.83)	I am in a good mood (3.57)	I am thinking deeply (3.32)
Red	I am angry (4.3)	Leave me alone (3.9)	I am thinking deeply (2.59)
Green	I am okay to talk (3.4)	I am in a good mood (3.38)	I am waiting (3.26)
Blue	I am relaxed (3.8)	I am in a good mood (3.65)	I am waiting (3.42)
Teal	I am relaxed (3.82)	I am in a good mood (3.43)	I am ok to talk (3.42)
Purple	I am waiting (3.24)	I am okay to talk (3.12)	I am in a good mood (3.08)
Orange	I am in a good mood (3.15)	I am okay to talk (3.07)	I am waiting (3.04)
Yellow	I am in a good mood (3.57)	I am relaxed (3.34)	I am okay to talk (3.33)
White	I am relaxed (4.19)	I am in a good mood (3.83)	I am thinking deeply (3.59)

Table 5.18: Representing feelings through colors as the respondents would express if in the same scenario as that in the picture – All responses

Feelings	Red2	Green2	Blue2	Teal2	Purple2	Orange2	Yellow2	White2
I am relaxed	1.65	3.23	3.85	3.47	3.01	2.89	3.42	4.11
Leave me alone	3.91	2.72	2.39	2.43	2.78	2.81	2.54	2.47
I am waiting	2.56	3.23	3.59	3.42	3.29	3.16	3.29	3.41
I am thinking deeply	2.55	2.83	3.17	3.01	2.91	2.72	2.72	3.22
I am ok to talk	2.03	3.16	3.36	3.18	3.27	3.18	3.36	3.72
I am angry	4.14	2.61	2.21	2.26	2.58	2.87	2.41	1.97
I am in a good mood	2.02	3.25	3.73	3.39	3.08	3.07	3.56	3.72

Table 5.19: Representing feelings through colors as the respondents would express if in the same scenario as that in the picture – Most preferred responses (Mean values in brackets)

Color	Feeling 1	Feeling 2	Feeling 3
Red	I am angry (4.1)	Leave me alone (3.91)	I am waiting (2.56)
Green	I am in a good mood (3.25)	I am okay to talk (3.16)	I am waiting, I am relaxed (3.23)
Blue	I am relaxed (3.85)	I am in a good mood (3.72)	I am waiting (3.58)
Teal	I am relaxed (3.46)	I am waiting (3.41)	I am in a good mood (3.39)
Purple	I am waiting (3.29)	I am okay to talk (3.27)	I am in a good mood (3.08)
Orange	I am okay to talk (3.18)	I am waiting (3.16)	I am in a good mood (3.07)
Yellow	I am in a good mood (3.55)	I am relaxed (3.42)	I am okay to talk (3.36)
White	I am relaxed (4.11)	I am in a good mood, I am okay to talk (3.72)	I am waiting (3.41)

5.3.3 Response of participants about digital crafts – qualitative description

In the descriptive section, participants mentioned that they *appreciated* the idea of non-verbal expression when need through visual cues, it *was innovative, exciting, interesting* and *amazing* for them, the concept of LED jacket and tees could come useful for performances at their college fest and get together. It could be very helpful for assisted living, for education, etc. They suggested that if the LEDs were individually embroidered like the pearls, that would improve the aesthetic look and feel of the jacket. They had concerns about wash-ability, battery power, product longevity and reuse.

Chapter Summary: *This chapter discusses the findings of Experimental Study 1 which lead to testing of hypothesis 1 and validation of theoretical model for non-verbal communication with digitally crafted textile wearables. Experimental study 2 tests hypotheses 2 and 3 with color connotations for expressing emotions and feelings in the given social context. Further discussions will be reported in the next chapter.*

Chapter 6

Discussion

This chapter presents a summary of findings of the thesis, contributions, limitations and scope for further work have also been mentioned. A design heuristic framework for designing digital crafts has been elaborated along with a motif vocabulary for future reference.

6.1 Introduction

The main findings of the research have been discussed with reference to statistical and qualitative tabulations in Chapter 4 and 5. The Chapter presents a design heuristic framework along with a motif vocabulary as contribution to existing literature for other designers and researchers in related domains for reference and encourages research on digital crafts of India. Contributions made by the present research and scope for further research have been mentioned.

6.2 Role of traditional textiles of India in reinforcing positive emotions and positive personality traits among young female users

The research through the first exploratory study evaluates the role of traditional textiles of India in evoking emotions among young female users. Figures 4.3-4.6, reveal that positive emotions are evoked much higher than the negative emotions. The data collected reveals that respondents provided 81% positive color connotations and 19% negative connotations for textile colors (Table 4.2). The responses were associated with 89% positive personality traits and 11% negative personality traits in the opinion of the respondents (Table 4.3). These findings affirm the fact that textiles, particularly traditional textiles of India as in the image board used as tool for photo elicitation cultural probe, evoke more of positive attributes in the respondents.

6.3 Role of user centric design process in designing culture-specific digital crafts

Chapter 4 (Section 4.4) elaborates upon the user centric design process followed in this research, from understanding users, designing, evaluating (experiments of Chapter 5) and drawing implications for further work. First, user behaviour has been understood

pertaining to boundaries, comfort levels and emotions experienced in specific contexts, to be able to design culture specific digital craft wearables that can enhance user's self-expression in their social space pertaining to these attributes. Designing any textile that could change visual or tactile cues would have not made as much of an enriched interface as is demonstrated by the three scarves particularly in the process followed in crafting them, as has been pointed out by respondents of Experimental Studies. For experimental Study 2, the respondents who specialise in Fashion Design, pointed out that integrating LEDs on the top surface as part of the embroidery would have made the LED jacket aesthetically more pleasing, like the scarves. The LED jacket comprises LED strip attached to the inner lining along the edges. The respondents exhibited *enthusiastic* and *optimistic* attitude towards usage of such crafts in their daily life. Understanding users, designing, evaluating for taking their feedback and then iterating and re-testing forms the core of user centric design process, as evident from finding of user feedback from experimental studies. These digital craft interfaces can not only cater to the Indian user group but also global customer segments through a niche segment of products as part of designers' craft product collections, once developed with better craftsmanship and quality finishing.

6.4 Role of digital craft wearables in conveying *emotions* and *feelings* non-verbally in the social space of users

Through experimental studies it has been found that dynamic textiles (the four LED embedded digital craft wearables) have been found to significantly convey and evoke *emotions* and *feelings* in respondents than the static textiles. As part of experimentation of digital crafts for non-verbal self-expression, role *emotions* and *feelings* have been studied in detail by evaluation of the three hypotheses. Static traditional textiles also evoke and convey moods and emotions of the wearer to the viewers in a social space and vice versa. But, through a textile capable of changing visual cues, the capacity of the individual for non-verbal self-expression (as experimented for *emotions* and *feelings* – Hypotheses1, 2 and 3) is significantly enhanced. It is also imperative to note that dynamicity of textile wearables has been intended to be used only when required for non-verbal self-expression by the wearer and not at all the times. Otherwise, the electronic elements remain neatly integrated in the textile as part of its design motifs and patterns. Through qualitative analysis it has been found that certain emotions can be significantly expressed by a specific or a group of closely related colors that could build a vocabulary of colors that could be used for expressing specific *emotions* (Table 5.10-5.11) and *feelings* (Table 5.16-5.19). The

social space in the experiments conducted were scenarios of *cafeteria, office*, *while commuting* as described in the experimental procedure (Annexure 6e). The respondents interacted with other users (Experiment 1) or took part in a photo elicitation study (Experiment 2) through the visual cues of digital craft prototypes. The responses revealed that significant levels of *emotions* and *feelings* could be expressed by the dynamic textiles than the static textiles in their social space when needed.

6.5 Design Heuristic framework for designing digital crafts in Indian context

On the basis of user centric design process followed in Chapter 4, the following design heuristic framework is being proposed, as depicted in Figure 6.1. The framework elaborates the user centric approach in the identification phase, where after need identification, identifying specific textile craft design elements and embedded electronic technology, in synchronisation with each aspect is required. *Ideation, concept generation, concept selection*, *refinement of final concepts, user testing and iteration* are the same as the generic user centric approach. User testing and iteration are repetitive in nature unless the objectives of the experiment being conducted are fulfilled. Iteration may occur in any of the steps of the entire process based on user feedback. For instance, in Experiment 2, for the LED jacket, the user feedback was to integrate LEDs as part of embroidery on the top surface instead of inside. Although the purpose of the experiment 2 is fulfilled, as the hypotheses was to evaluate whether visual cues (colors) could enable significant expression of emotions and feelings in the social space of users, the prototype itself could be iterated upon based on feedback. This would require redesign of circuit based on number of LEDs to be incorporated, the control mechanism and power requirements of the circuit.

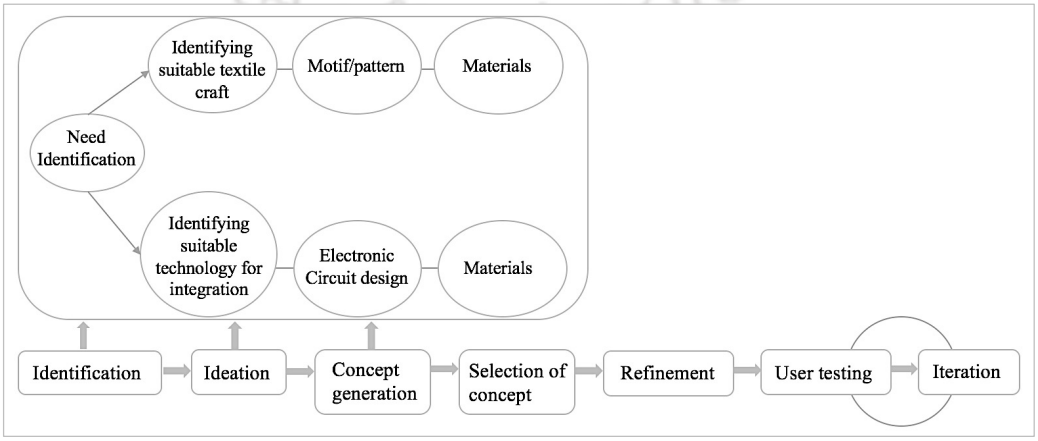
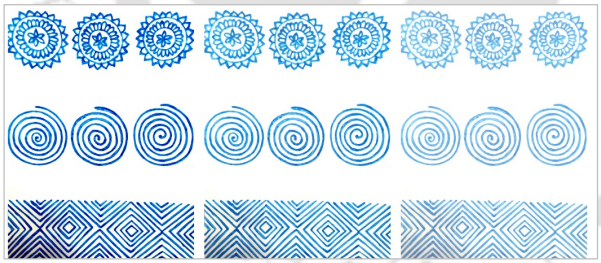


Figure 6.1: Design heuristic framework for designing digital craft wearables

The thesis also presents a brief vocabulary of traditional textile design craft elements for designers and researchers to assist them in identification and ideation phase. Table 6.1 presents few motifs and the uniqueness of the craft which could be integrated with electronic elements as mentioned further that could be seamlessly combined on textile surface for creating culture specific digital craft interfaces. There are three categories of textile crafts – Embroidered (*Zardozi, ari work, Chikankari, Lambani, Kutchi, Gota, Pipli, Kantha,* Mirror*, Phulkari, Naga* conch shell work); Woven (*Zari,* silk*, ikat, dhurries*, Kashmiri rugs); and, painted, printed or resist dyed (*Batik, Kalamkari,* Block print, *Madhubani, Bandhani*). Although there are several examples for each category from different states of India, only few examples have been listed for understanding. The three-dimensional elements or two dimensional patterns can be replaced/integrated with LEDs, Adafruit Lilypad Arduino, sensors, connected with conductive thread for circuitry, conductive thread for weaving, heating pads, motors, etc. for multiple functionalities depending in requirements.

The onus lies with the designers and researchers that craft persons can be trained selectively to craft digitised products as part of their on-going production activities. Upgradation programmes can be undertaken and specific craft clusters, NGOs and Government initiatives can initiate small scale development, training and retails of digital crafts in near future.



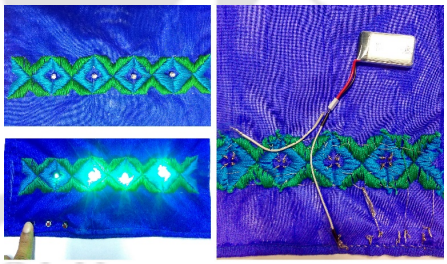
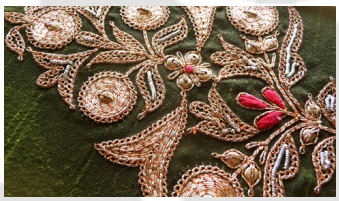
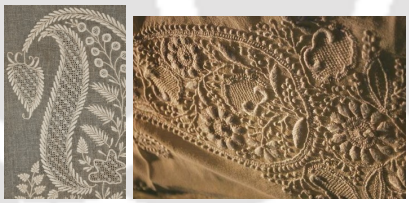


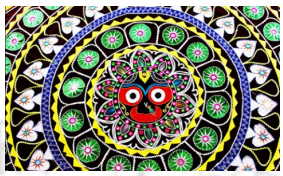
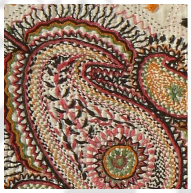
Figure 6.2: Block printed sample designed from heat sensitive blue ink; **Figure 6.3:** LED embedded prototype with *Phulkari* embroidery – front and back side of prototype

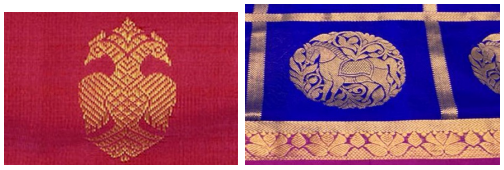
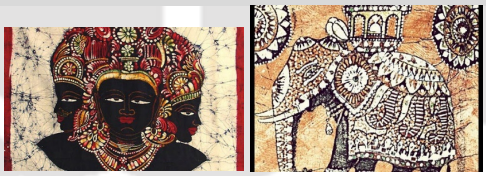
LED embedded prototype 1 and 2 inspired from *Zardozi* and *Kantha* are two examples to be mentioned from this thesis in the *embroidered* category. Woven designs can easily integrate conductive threads and sensors within their elaborate designs. Conductive ink, thermo-chromic ink, etc. can be used for painting and printing. Although Prototype 3, inspired from *Madhubani* painting demonstrates positioning of conventional LEDs along with design elements. Prototype as depicted in Figure 6.2 (earlier depicted in Figure 4.20,

column 3) is a block printed sample created from heat sensitive ink which appears and disappears on application of heat. The *Phulkari* embroidery (Table 6.1) has inspired designing of an LED embedded prototype depicted in Figure 4.20 column 1 and Figure 6.3. The conductive thread circuit was neatly interlaced in the 3D patterns of the embroidered back fabric. These samples (Figure 6.2-6.3) were not taken for experimental evaluation, but find interesting applications in clothing and interior.

Table 6.1: Motif vocabulary

Category	Traditional Textile Motifs/ Patterns	Description of Craft
Embroidered		
Zardozi		Traditional embridery with precious, semi-precious stones, metal, sequins and gold, silver or mettalic threads. Inspired design of Scarf 1 *Aster*.
Ari work		Embroidery done with gold threads originally with floral ornate designs for a rich textile surface.
Chikankari		Shadow work or pulled thread embroidery that is done on fine *muslin* fabrics to create delicate textures with tone on tone effect.
Lambani Embroidery		Bold and colorful embroidery with large pieces of stones, beads, mirrors, mettalic elements.
Kutch Embroidery		Geometric, floral patterns and animal figures in bold and colorful threads, mirrors and beads embroidered to create a rich surface.

Gota embroidery		Embroidery done with lace couching and other techniques for a 3D look, very common for borders in contemporary clothing.
Pipli	 	Traditional patchwork with colorful elements for wall hangings, parasols, etc with design from flora, fauna, local deities and mythology
Kantha	 	Running stitch embroidery done on a quilted fabric. Adopted for designing Scarf 2, *Iris*.
Mirror work	 	Elaboarte embroidery in colorful threads, bold colors with multitude of mirrors to ward off the evil, as per the belief of craftsmen.
Phulkari	 	Traditional bridal shawl embroidered by grandmother to be gifted to the bride on her wedding day with auspicious motifs covering entire fabric.
Naga conch shell embroidery	 	The north-eastern states have specific textiles with specific meanings for warriors, head men, protetcion, brides, farmers, etc. The example figure depicts a reputed Naga clothing from the state of Nagaland.
Woven		
Zari woven	 	Woven brocades are distinct in different states of India. Example figures depict *kanjeevaram* from South India.

Silk with butis		Brocade sarees have intricate butis along their body as extra weft yarns or as part of jacquard weaving.
Ikat		Tie-dyed resist techniques are unique in Gujarat and Andhra Pradesh. The figure depicts Patola saree from Gujarat, Western India.
Dhurries		Dhurries are handwoven with geometric patterns and myriad textures all over the country.
Kashmiri rug		Comprise elaborate persian designs hand-tufted on vertical looms with naturally dyed yarns for unique textures..
Painted/Printed		
Batik		Wax resist technique common in West Bengal, East India.
Kalamkari		Produce fabrics, handpainted with natural dyes with mythological designs and designs inspired form nature.
Block print		Common in Western states of India with uniques styles of block prints, traditionallly done in natural colors and wooden blocks.

Madhubani		Hand painted techniques from Eastern India with primitive motifs in bright colors and prominent black outlines. Inspiration for LED scarf 3, *Nymphaea*.
Bandhani		Resist dye techniques with cotton threads tied in small knots to fomr patterns. The knotting pattern styles generate the name of the type of craft produced.

The images of textile motifs in Table 6.1, have been obtained from the internet for reference [Untitled illustrations of *Zardozi, Ari* work, *Chikankari, Lambani* Embroidery, *Kutch* Embroidery, *Gota* embroidery, *Pipli*, *Kantha*, Mirror work, *Phulkari, Naga* conch shell embroidery, *kanjeevaram*, Silk *butis*, *Ikat*, *Dhurries*, *Kashmiri* rug, *Batik*, *Kalamkari*, Block print, *Madhubani*, and, *Bandhani*]. And, the descriptions for traditional textile crafts in Table 6.1, have been obtained from Bhatnagar, (2004), Bhatnagar, (2005), Ambalal, (1987), Chisti, (2010), Gillow and Bernard, (2008), and, Katiyar, (2009).

6.6 Summary of contributions

The thesis has theoretical and practical contributions. The theoretical contributions include (i) Studying the aspects of personality, perception, preferences and cultural connotations of traditional textiles of India among young female students. There is massive documentation of textile craft practices of India, ethnographic and subjective writings. The exploratory study aims at contributing to perceptual aspects through a qualitative study, so that designers, researchers, manufacturers and marketers can probe in detail to uphold the cultural diversity of Indian textile traditions. (ii) The Design Heuristic Framework for designing digital crafts (Figure 6.1), a theoretical framework, has been positioned in this thesis to design a set of digital craft prototypes for user evaluation. The framework could assist designers and researchers to design digital crafts in their respective domains for brand building or research in the domain of traditional textiles of India. (iii) Of the several applications of digital crafts for experimentation, non-verbal expression of emotions and feelings was studied in detail. The thesis proposes a new measure for quantification of non-verbal communication through digital crafts in the social space of the Indian users. The

variables have been experimented and validated through Experimental study 1 and 2. The seven questions asked to the respondents rated on a 5-point semantic differential scale (1=disagree, 5=agree) have been mentioned in the Tables 5.5-5.7 and Annexure 7. (iv) The theoretical model for quantification of aspects of non-verbal expression through evaluation of effect of positive emotions, negative emotions, aesthetics and non-verbal self-expression in the social space with respect to Technology Acceptance has been experimented and validated in Experiment 2 (Figure 5.1-5.3). The model can be elaborated by researchers in similar domain while experimenting with context-specific applications.

The practical applications include: (i) The user centric design process demonstrates the potential of merging embedded electronics with elaborate textile crafting traditions of India, which was explored limitedly in literature reviewed. 4 prototypes have been evaluated with 274 young respondents and have shown positive attitude towards digital crafts, their importance, design and usage which demonstrates high acceptance of a niche segment of culture specific products of Indian users and is promising for global markets as well. (ii) The experimental studies – set-up, design and procedure demonstrate the methodology adopted in this research, where the context of evaluation was non-verbal self-expression through digital crafts in the social space of users. Researchers in similar domain could design context specific experiments and enrich the sub-domain of digital crafts with respect to varied traditional textile crafts of India.

6.7 Limitations of research and scope for future work

More of traditional craft designs as prints, weaves, knitting, embroideries need to be explored with embedded electronics for designing artificially intelligent crafts for specific applications. Gender specific studies have been conducted as part of this thesis, so gender neutral products and products for different categories for specific studies with different user groups – geriatric, special needs, children, universal design – could be explored and evaluated. Exploring segments for (textile) wearables such as – interior, automobile, military, health, etc. specifically for an in-depth study could also be undertaken. Scope for improving usability of the interfaces also can be done by refining the prototypes and making them seamless further. Contextual application of color vocabulary needs to be studied as connotations of colors may vary from culture to culture, user to user and different social, formal or informal settings. Larger sample size, broader sample groups for validation, comparative, cross-cultural studies and detailed statistical evaluation can be carried out.

Chapter Summary: *This chapter discusses the summary of key findings pertaining to traditional textiles, user behavior, user centered design process for designing digital crafts, contributions made by this research, few limitations and scope for further work have been reported.*

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Annexure

Annexure 1: Un-Filled Questionnaire – Exploratory Study 1

Survey on 'Moods evoked by traditional sarees'

Name - Age - Occupation - Place -............................

1. Please observe the images below and tick appropriate **emotions** evoked in you; (low (1) to high (7) in the grids attached to this sheet.

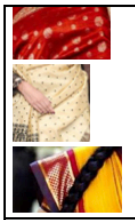
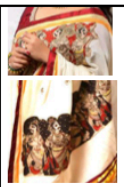
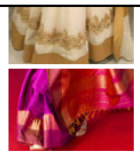
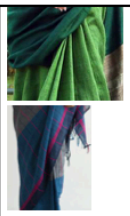
	Emotions	1	2	3	4	5	6	7
1	Admiration							
2	Amazement							
3	Joy							
4	Serenity							
5	Interest							
6	Awe							
7	Annoyance							
8	Boredom							
9	Sadness							
10	Apprehension							

	Emotions	1	2	3	4	5	6	7
1	Admiration							
2	Amazement							
3	Joy							
4	Serenity							
5	Interest							
6	Awe							
7	Annoyance							
8	Boredom							
9	Sadness							
10	Apprehension							

	Emotions	1	2	3	4	5	6	7
1	Admiration							
2	Amazement							
3	Joy							
4	Serenity							
5	Interest							
6	Awe							
7	Annoyance							
8	Boredom							
9	Sadness							
10	Apprehension							

Annexure 1: Un-Filled Questionnaire – Exploratory Study 1- Page 1

2. What kind of designs do you prefer on the saree and Why? Please tick below-

					
Geometric	Floral, paisleys	Mythological, Festive, Kalash, etc.	Plain body with heavy border	Solid colors	Any other

3. What do the following colors evoke in you, please mention –

S. No.	Colors		Meanings evoked in you
1	Red		
2	Blue		
3	Yellow		
4	Green		
5	Purple		
6	Brown		
7	Black		
8	White		
9	Grey		
10	Gold		
11	Silver		
12	Tints		

4. What would be your color preference for a traditional saree?
5. Do colors in the dress change your moods? Yes/ No
6. Do you think dresses worn have a capacity to uplift your mood? Yes/ No
7. Do you make a conscious decision while purchasing a dress? Yes/ No
8. Is the dress worn an extension to your personality? Yes/ No
9. Are you aware of the choices made for buying dresses in different moods? Yes/No
10. What does 'mood' mean to you? Please describe.

.....

Annexure 1: Un-Filled Questionnaire – Exploratory Study 1- Page 2

11. What colors / sarees would you wear when you are in following moods, please mention –

S. no.	Moods	Colors	Sarees
1	Good		
2	Bad		
3	Lazy		
4	Cheerful		
5	Depressed		
6	Adventurous		
7	Ease		
8	Rejuvenated		
9	Enjoyment		
10	Satisfaction		

12. Please tick the appropriateness of occasions where these sarees can be worn –

Sarees	Office	Festival	Wedding	Party	Casual	Any other
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

13. Please describe the model wearing the saree –

Saree 1		Saree 7	
Saree 2		Saree 8	
Saree 3		Saree 9	
Saree 4		Saree 10	
Saree 5		Saree 11	
Saree 6		Saree 12	

Annexure 1: Un-Filled Questionnaire – Exploratory Study 1- Page 3

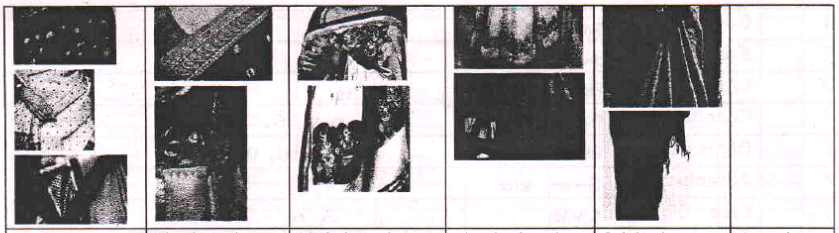
Annexure 2: Filled Questionnaire – Exploratory Study 1

Name Simran Agarwal Age 19 Occupation 11th Std Place Kolkata (5)

Survey on 'Moods evoked by traditional sarees'

1. Please observe the images below and tick appropriate **emotions** evoked in you; (low (1) to high (7) in the grids attached to this sheet.

2. What kind of designs do you prefer on the saree and Why? Please tick below-



Geometric	Floral, paisleys	Mythological, Festive, Kalash, etc	Plain body with heavy border	Solid colors	Any other
			✓		

3. What do the following colors evoke in you, please mention -

S. No.	Colors		Meanings evoked in you
1	Red		Traditional
2	Blue		Artistic Fantasy, aquatic.
3	Yellow		Sunrise
4	Green		Scenary
5	Purple		Fantasy
6	Brown		Texture
7	Black		Serenity
8	White		Peace
9	Grey		Ugly
10	Gold		Exclusiveness
11	Silver		Gorgeous
12	Tints		All time favourites, mood enlightning.

4. What would be your color preference for a traditional saree? Red + Green
5. Do colors in the dress change your moods? Yes/ No
6. Do you think dresses worn have a capacity to uplift your mood? Yes/ No
7. Do you make a conscious decision while purchasing a dress? Yes/ No
8. Is the dress worn an extension to your personality? Yes/ No
9. Are you aware of the choices made for buying dresses in different moods? Yes/No

Annexure 2: Filled Questionnaire – Exploratory Study 1 – Page 1

10. What does 'mood' mean to you? Please describe.

Mood is a feeling of mind towards something like happy or sad or angry mood.

11. What colors / sarees would you wear when you are in following moods, please mention –

S. no.	Moods	Colors	Sarees
1	Good	light blue, pink	3, 5
2	Bad	Dark green	1, 10
3	Lazy	Pale yellow, grey	12
4	Cheerful	Pink, red	8, 7, 5.
5	Depressed	Black	12, 10, 11.
6	Adventurous	Green, Blue	7, 8.
7	Ease	White	9, 4
8	Rejuvenated	Orange	1, 5, 7, 8,
9	Enjoyment	Red	5, 8
10	Satisfaction	Blue	1, 5, 7, 8

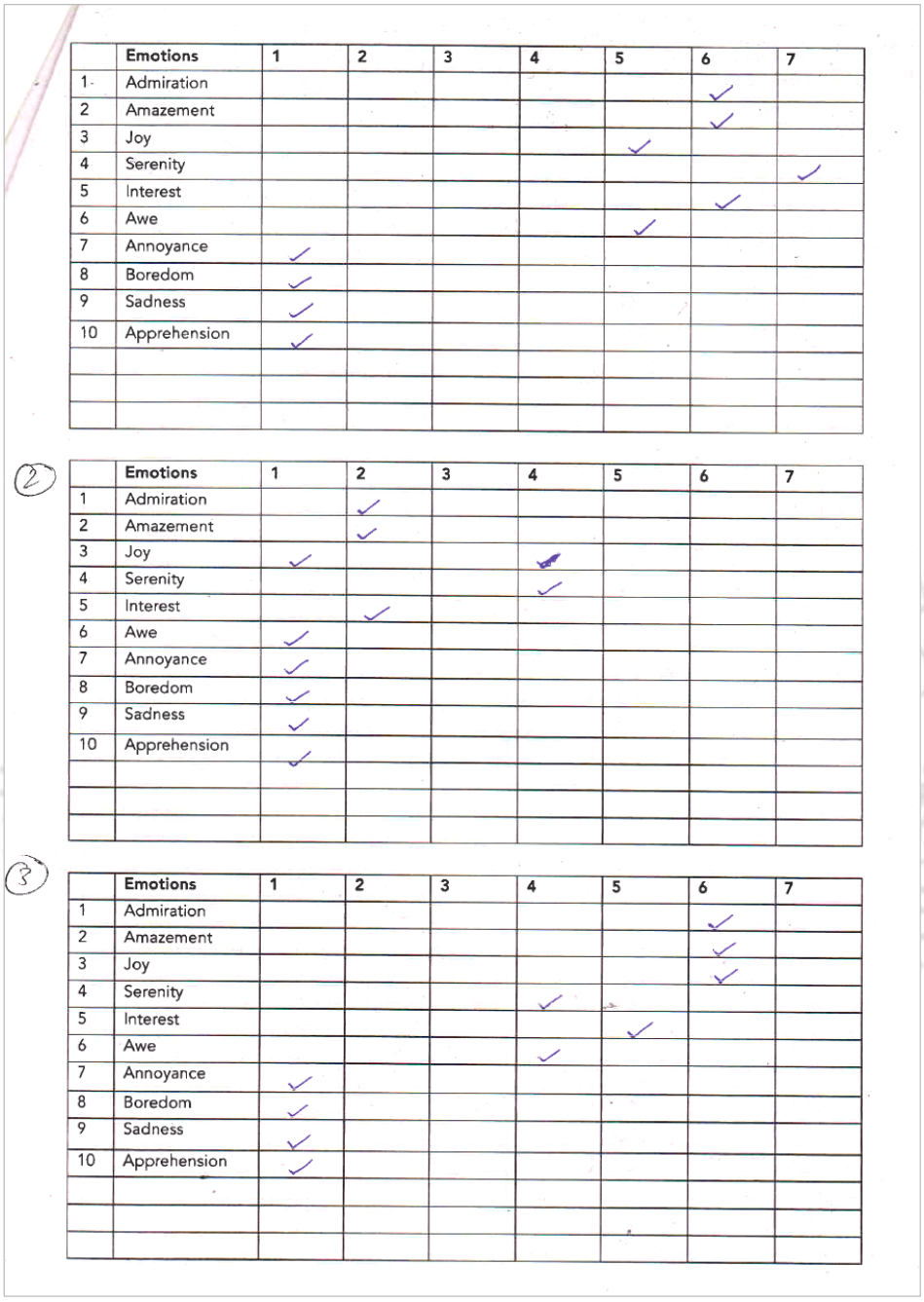
12. Please tick the appropriateness of occasions where these sarees can be worn –

Sarees	Office	Festival	Wedding	Party	Casual	Any other
1		✓	✓	✓	✓	
2			✓			
3		✓	✓	✓		
4	✓	✓			✓	
5		✓	✓	✓		
6	✓				✓	
7		✓	✓	✓	✓	
8		✓	✓	✓	✓	
9		✓			✓	
10	✓				✓	
11	✓				✓	
12					✓	

13. Please describe the model wearing the saree –

Saree 1	Beautiful, Decent	Saree 7	Decent, Amazing
Saree 2	~~Ques~~: Confident	Saree 8	Decent, Beautiful
Saree 3	Pretty	Saree 9	Beautiful
Saree 4	Decent	Saree 10	Decent
Saree 5	Gorgeous, Decent	Saree 11	Aggreaire.
Saree 6	Formal	Saree 12	Pathetic

Annexure 2: Filled Questionnaire – Exploratory Study 1 – Page 2



	Emotions	1	2	3	4	5	6	7
1	Admiration						✓	
2	Amazement						✓	
3	Joy					✓		
4	Serenity							✓
5	Interest						✓	
6	Awe					✓		
7	Annoyance	✓						
8	Boredom	✓						
9	Sadness	✓						
10	Apprehension	✓						

(2)

	Emotions	1	2	3	4	5	6	7
1	Admiration		✓					
2	Amazement		✓					
3	Joy	✓			✓			
4	Serenity				✓			
5	Interest		✓					
6	Awe	✓						
7	Annoyance	✓						
8	Boredom	✓						
9	Sadness	✓						
10	Apprehension	✓						

(3)

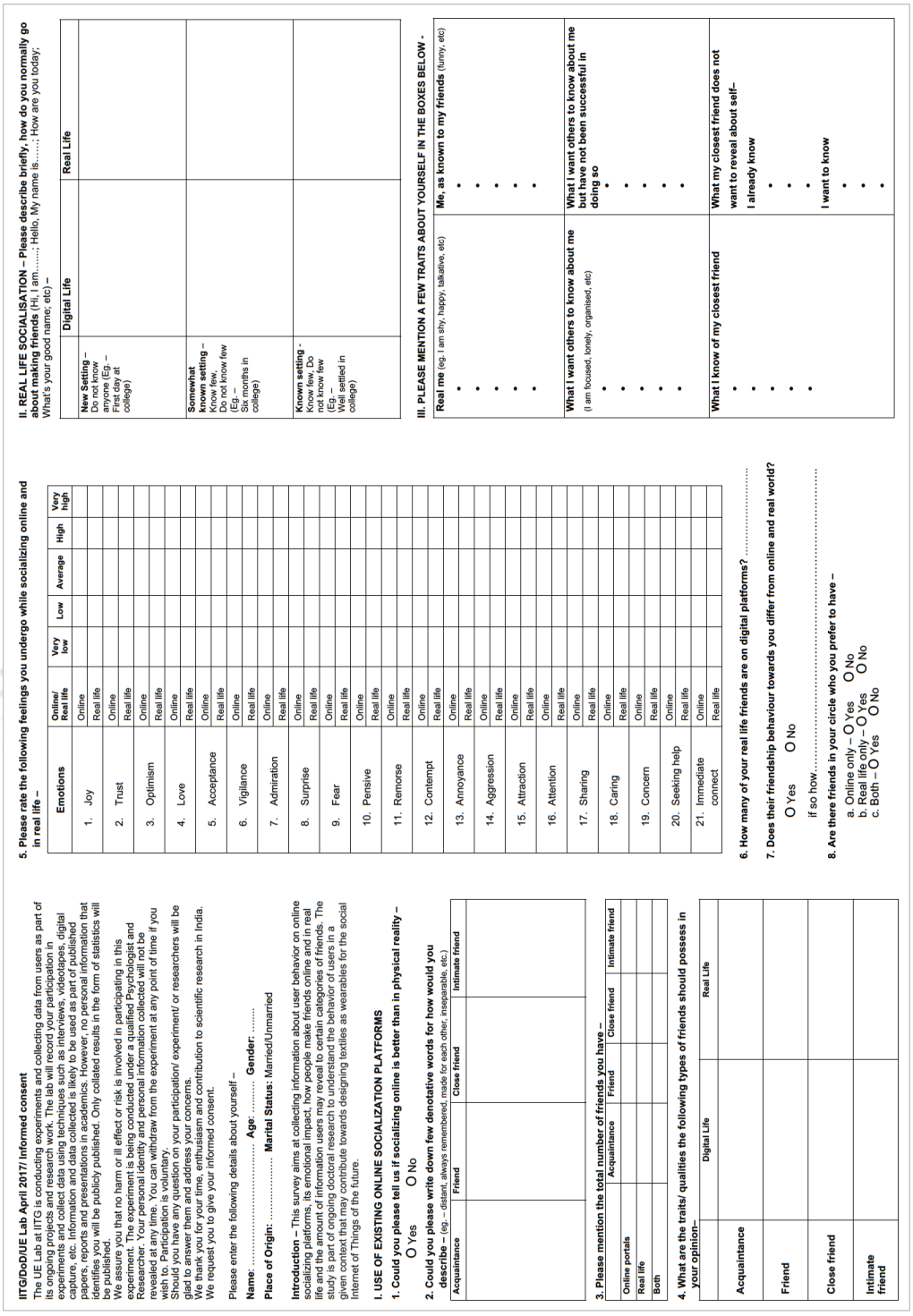
	Emotions	1	2	3	4	5	6	7
1	Admiration						✓	
2	Amazement						✓	
3	Joy						✓	
4	Serenity				✓			
5	Interest					✓		
6	Awe				✓			
7	Annoyance	✓						
8	Boredom	✓						
9	Sadness	✓						
10	Apprehension	✓						

Annexure 2: Filled Questionnaire – Exploratory Study 1 – Page 3

Annexure 3: 25 saree Image board – Tool – Exploratory Study 1

Annexure 3: 25 saree Image board – Tool – Exploratory Study 1. [Untitled Illustrations Sarees 1-25]

Annexure 4: Un-Filled Questionnaire – Exploratory Study 2



IITG/DoD/UE Lab April 2017/ Informed consent

The UE Lab at IITG is conducting experiments and collecting data from users as part of its ongoing projects and research work. The lab will record your participation in experiments and collect data using techniques such as interviews, videotapes, digital capture, etc. Information and data collected is likely to be used as part of published papers, reports and presentations in academics. However, no personal information that identifies you will be publicly published. Only collated results in the form of statistics will be published.

We assure you that no harm or ill effect or risk is involved in participating in this experiment. The experiment is being conducted under a qualified Psychologist and Researcher. Your personal identity and personal information collected will not be revealed at any time. You can withdraw from the experiment at any point of time if you wish to. Participation is voluntary.

Should you have any question on your participation/ experiment/ or researchers will be glad to answer them and address your concerns.

We thank you for your time, enthusiasm and contribution to scientific research in India. We request you to give your informed consent.

Please enter the following details about yourself –

Name: ..... **Age:** ..... **Gender:** .....

Place of Origin: ..... **Marital Status:** Married/Unmarried

Introduction – This survey aims at collecting information about user behavior on online socializing platforms, its emotional impact, how people make friends online and in real life and the amount of information users may reveal to certain categories of friends. The study is part of ongoing doctoral research to understand the behavior of users in a given context that may contribute towards designing textiles as wearables for the social Internet of Things of the future.

I. USE OF EXISTING ONLINE SOCIALIZATION PLATFORMS

1. Could you please tell us if socializing online is better than in physical reality –

O Yes O No

2. Could you please write down few denotative words for how would you describe – (eg. – distant, always remembered, made for each other, inseparable, etc.)

Acquaintance	Friend	Close friend	Intimate friend

3. Please mention the total number of friends you have –

	Acquaintance	Friend	Close friend	Intimate friend
Online portals				
Real life				
Both				

4. What are the traits/ qualities the following types of friends should possess in your opinion–

	Digital Life	Real Life
Acquaintance		
Friend		
Close friend		
Intimate friend		

5. Please rate the following feelings you undergo while socializing online and in real life –

Emotions	Online/ Real life	Very low	Low	Average	High	Very high
1. Joy	Online					
	Real life					
2. Trust	Online					
	Real life					
3. Optimism	Online					
	Real life					
4. Love	Online					
	Real life					
5. Acceptance	Online					
	Real life					
6. Vigilance	Online					
	Real life					
7. Admiration	Online					
	Real life					
8. Surprise	Online					
	Real life					
9. Fear	Online					
	Real life					
10. Pensive	Online					
	Real life					
11. Remorse	Online					
	Real life					
12. Contempt	Online					
	Real life					
13. Annoyance	Online					
	Real life					
14. Aggression	Online					
	Real life					
15. Attraction	Online					
	Real life					
16. Attention	Online					
	Real life					
17. Sharing	Online					
	Real life					
18. Caring	Online					
	Real life					
19. Concern	Online					
	Real life					
20. Seeking help	Online					
	Real life					
21. Immediate connect	Online					
	Real life					

6. How many of your real life friends are on digital platforms? .....

7. Does their friendship behaviour towards you differ from online and real world?

O Yes O No

If so how.....

8. Are there friends in your circle who you prefer to have –

a. Online only – O Yes O No
b. Real life only – O Yes O No
c. Both – O Yes O No

II. REAL LIFE SOCIALISATION – Please describe briefly, how do you normally go about making friends (Hi, I am.....; Hello, My name is.....; How are you today; What's your good name; etc) –

	Digital Life	Real Life
New Setting – Do not know anyone (Eg – Friend of a friend at college)		
Somewhat known setting – Know few, Do not know few (Eg. – Six months in college)		
Known setting - Know few, Do not know few (Eg. – Well settled in college)		

III. PLEASE MENTION A FEW TRAITS ABOUT YOURSELF IN THE BOXES BELOW -

Real me (eg. I am shy, happy, talkative, etc)	**Me, as known to my friends** (funny, etc)
•	•
•	•
•	•
•	•
•	•
What I want others to know about me (I am focused, lonely, organised, etc)	**What I want others to know about me but have not been successful in doing so**
•	•
•	•
•	•
•	•
•	•
What I know of my closest friend	**What my closest friend does not want to reveal about self– I already know**
•	•
•	•
•	•
•	**I want to know**
	•
	•
	•

Annexure 4: Un-Filled Questionnaire – Exploratory Study 2 – Page 1-3

IV. Rate by circling a point between 1-10 on each axis indicating the limits of boundaries you would create when socialising with – (centre= 0, perimeter= 10)

1. KNOWN FRIENDS

2. STRANGER

3. INTIMATE FRIEND

V. (1.) PLEASE TICK THE TYPES OF INFORMATION YOU DON'T MIND REVEALING WHILE SOCIALIZING WITH SPECIFIED INDIVIDUALS/ GROUPS

Types of Information	Stranger from different community	Stranger from same community	Acquaintance	Social Friend	Close Friend	Intimate Friend
Name						
Age						
Designation						
Education						
Job description						
Profile picture						
Place of origin						
Hobbies						
Phone number						
Email address						
Food Habits						
Movies						
Books						
Sports						
Your image gallery						
Weekend plans						
Marital status						
Social habits (Smoking, Drinking, etc)						

2. Please list 5 positive traits that you identify within yourself –

a)
b)
c)
d)
e)

Please tick if you would like to share the 5 positive traits of yourself with the following categories of people –

○ Stranger from different community	○ Stranger from same community	○ Acquaintance	○ Social Friend	○ Close Friend	○ Intimate Friend

3. Please list 5 negative traits that you identify within yourself –

a)
b)
c)
d)
e)

Please tick with whom you don't mind sharing the 5 negative traits of yourself with the following categories of people –

○ Stranger from different community	○ Stranger from same community	○ Acquaintance	○ Social Friend	○ Close Friend	○ Intimate Friend

4. Please mention the percentage of comfortability (0-100%) about sharing the below mentioned details with the following categories of people -

Types of Information	Stranger from different community	Stranger from same community	Acquaintance	Social Friend	Close Friend	Intimate Friend
Sharing your Past						
1. Social						
2. Academic						
3. Professional						
4. Relationships						
5. Family						
Initiating a conversation with						

VI. EXPRESSION OF SELF

1. **What percentage (0-100%) role do dress/ attire/ clothing play, according to you, in projecting your true self to the outside world?**

   .....

2. **Do you believe your dress, textiles you use can be made more useful and helpful in your socialization?**

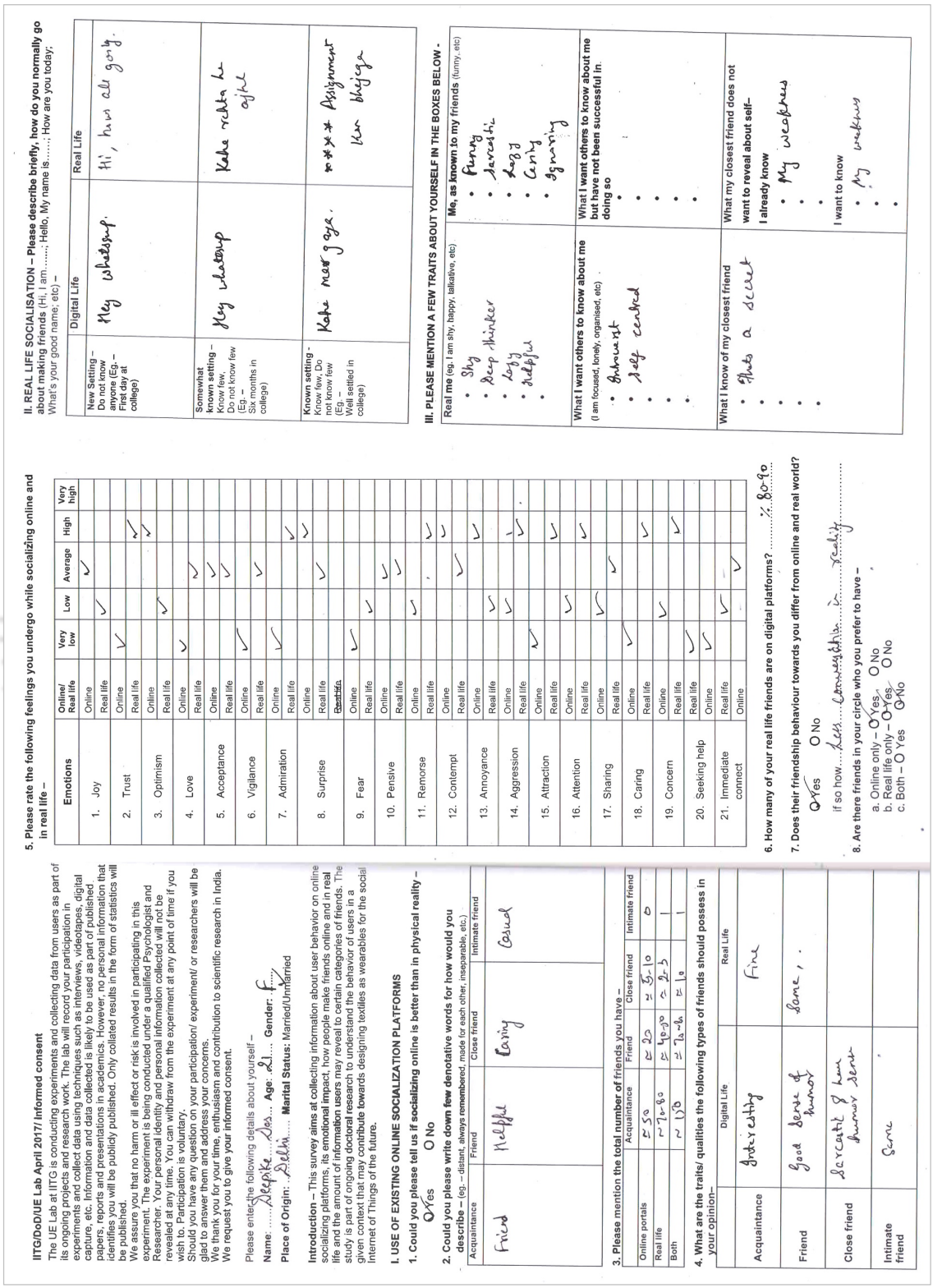
   ☐ Yes ☐ No ☐ Maybe

3. **Please mention the percentage (0-100) of feelings corresponding to the contexts that may be expressed –**

	Emotions	Office	School	College	Wedding	Park	Commuting (Bus, Train)
1	Joy						
2	Trust						
3	Optimism						
4	Love						
5	Vigilance						
6	Admiration						
7	Surprise						
8	Fear						
9	Pensive						
10	Remorse						
11	Annoyance						
12	Aggression						

Annexure 4: Un-Filled Questionnaire – Exploratory Study 2 – Page 4-6

Annexure 5: Filled Questionnaire – Exploratory Study 2



IITG/DoD/UE Lab April 2017/ Informed consent

The UE Lab at IITG is conducting experiments and collecting data from users as part of its ongoing projects and research work. The lab will record your participation in experiments and collect data using techniques such as interviews, videotapes, digital capture, etc. Information and data collected is likely to be used as part of published papers, reports and presentations in academics. However, no personal information that identifies you will be publicly published. Only collated results in the form of statistics will be published.

We assure you that no harm or ill effect or risk is involved in participating in this experiment. The experiment is being conducted under a qualified Psychologist and Researcher. Your personal identity and personal information collected will not be revealed at any time. You can withdraw from the experiment at any point of time if you wish to. Participation is voluntary.

Should you have any question on your participation/ experiment/ or researchers will be glad to answer them and address your concerns.

We thank you for your time, enthusiasm and contribution to scientific research in India.

We request you to give your informed consent.

Please enter the following details about yourself –

Name: ....Deepika.... **Age:** 21.... **Gender:** F....

Place of Origin: ...Delhi.... **Marital Status:** Married/Unmarried

Introduction – This survey aims at collecting information about user behavior on online socializing platforms, its emotional impact, how people make friends online and in real life and the amount of information users may reveal to certain categories of friends. The study is part of ongoing doctoral research to understand the behavior of users in a given context that may contribute towards designing textiles as wearables for the social Internet of Things of the future.

I. USE OF EXISTING ONLINE SOCIALIZATION PLATFORMS

1. Could you please tell us if socializing online is better than in physical reality –
Yes ○ No

2. Could you please write down few denotative words for how would you describe – (eg. – distant, always remembered, made for each other, inseparable, etc.)

Acquaintance	Friend	Close friend	Intimate friend
Friend	Helpful	Caring	Casual

3. Please mention the total number of friends you have –

	Acquaintance	Friend	Close friend	Intimate friend
Online portals	≥ 50	≥ 20	≥ 5-10	5
Real life	~ 70-80	≥ 40-50	≥ 2-5	1
Both	~ 150	≥ 70-80	≥ 10	1

4. What are the traits/ qualities the following types of friends should possess in your opinion–

	Digital Life	Real Life
Acquaintance	Trustworthy	Fine
Friend	Good sense of humour	Same, .
Close friend	Sarcasm & keen humour sense	
Intimate friend	Same	

5. Please rate the following feelings you undergo while socializing online and in real life –

Emotions	Online/ Real life	Very low	Low	Average	High	Very high
1. Joy	Online			✓		
	Real life		✓			
2. Trust	Online	✓			✓	
	Real life				✓	
3. Optimism	Online				✓	
	Real life		✓			
4. Love	Online	✓				
	Real life			✓		
5. Acceptance	Online			✓		
	Real life			✓		
6. Vigilance	Online		✓			
	Real life			✓		
7. Admiration	Online		✓			
	Real life				✓	
8. Surprise	Online				✓	
	Real life			✓		
	~~Real life~~					
9. Fear	Online	✓				
	Real life		✓			
10. Pensive	Online			✓		
	Real life			✓		
11. Remorse	Online		✓			
	Real life				✓	
12. Contempt	Online				✓	
	Real life			✓		
13. Annoyance	Online				✓	
	Real life		✓			
14. Aggression	Online		✓			
	Real life				✓	
15. Attraction	Online	✓				
	Real life				✓	
16. Attention	Online		✓			
	Real life			✓		
17. Sharing	Online		✓			
	Real life			✓		
18. Caring	Online	✓				
	Real life				✓	
19. Concern	Online		✓			
	Real life				✓	
20. Seeking help	Online	✓				
	Real life		✓			
21. Immediate connect	Online			✓		
	Real life		✓			

6. How many of your real life friends are on digital platforms? 80-90

7. Does their friendship behaviour towards you differ from online and real world?
✓ Yes ○ No
If so how....Less Commitment in reality.....

8. Are there friends in your circle who you prefer to have –
a. Online only – ○ Yes ○ No
b. Real life only – ○ Yes ○ No
c. Both – ○ Yes ○ No

II. REAL LIFE SOCIALISATION – Please describe briefly, how do you normally go about making friends (Hi, I am.....; Hello, My name is.....; How are you today; What's your good name; etc) –

	Digital Life	Real Life
New Setting – Do not know anyone (Eg. – First day at college)	Hey whatsup.	Hi, how all going.
Somewhat known setting – Know few, Do not know few (Eg. – Six months in college)	Hey whatsup	Kaha rehta hu ajkl
Known setting - Know few, Do not know few (Eg. – Well settled in college)	Kaha mast gya.	**** Assignment kon bhejga

III. PLEASE MENTION A FEW TRAITS ABOUT YOURSELF IN THE BOXES BELOW -

Real me (eg. I am shy, happy, talkative, etc)
- Shy
- Deep thinker
- Happy
- Helpful

Me, as known to my friends (funny, etc)
- Funny
- Sarcastic
- Loyal
- Caring
- Ignoring

What I want others to know about me (I am focused, lonely, organised, etc)
- Introvert
- Very cautious
- ...
- ...
- ...

What I want others to know about me but have not been successful in doing so
- ...
- ...
- ...
- ...
- ...

What I know of my closest friend
- Likes a secret
- ...
- ...
- ...
- ...

What my closest friend does not want to reveal about self– I already know
- My weakness
- ...
- ...
- ...

I want to know
- My weakness
- ...
- ...
- ...

Annexure 5: Filled Questionnaire – Exploratory Study 2 – Page 1-3

Annexure 5: Filled Questionnaire – Exploratory Study 2 – Page 4-6

V. Rate by circling a point between 1-10 on each axis indicating the limits of boundaries you would create when socialising with – (centre= 0, perimeter= 10)

1. KNOWN FRIENDS

2. STRANGER

3. INTIMATE FRIEND

V. (1.) PLEASE TICK THE TYPES OF INFORMATION YOU DON'T MIND REVEALING WHILE SOCIALIZING WITH SPECIFIED INDIVIDUALS/ GROUPS

Types of Information	Stranger from different community	Stranger from same community	Acquaintance	Social Friend	Close Friend	Intimate Friend
Name	✓	✓	✓	✓	✓	✓
Age	✗	✗	✓	✓	✓	✓
Designation	✗	✗	✗	✓	✓	✓
Education	✓	✓	✓	✓	✓	✓
Job description	✗	✗	✗	✗	✓	✓
Profile picture	✗	✗	✗	✓	✓	✓
Place of origin	✗	✗	✓	✓	✓	✓
Hobbies	✗	✗	✗	✗	✓	✓
Phone number	✗	✗	✗	✗	✓	✓
Email address	✗	✗	✓	✓	✓	✓
Food Habits	✗	✗	✗	✓	✓	✓
Movies	✗	✗	✗	✗	✓	✓
Books	✓	✓	✓	✓	✓	✓
Sports	✗	✗	✗	✗	✓	✓
Your Image gallery	✗	✗	✓	✗	✓	✓
Weekend plans	✗	✗	✗	✗	✓	✓
Marital status	✗	✗	✓	✓	✓	✓
Social habits (Smoking, Drinking, etc)	✗	✗	✗	✗	✓	✓

2. Please list 5 positive traits that you identify within yourself –

a) Enthusiastic
b) Helpful
c) Somewhat Self centred
d) Jolly
e)

Please tick if you would like to share the 5 positive traits of yourself with the following categories of people –

○ Stranger from different community	○ Stranger from same community	○ Acquaintance	○ Social Friend	✓ Close Friend	○ Intimate Friend

3. Please list 5 negative traits that you identify within yourself –

a) Egoistic
b) Introvert
c) Shyness
d)
e)

Please tick with whom you don't mind sharing the 5 negative traits of yourself with the following categories of people –

○ Stranger from different community	○ Stranger from same community	○ Acquaintance	✓ Social Friend	○ Close Friend	○ Intimate Friend

4. Please mention the percentage of comfortability (0-100%) about sharing the below mentioned details with the following categories of people -

Types of Information	Stranger from different community	Stranger from same community	Acquaintance	Social Friend	Close Friend	Intimate Friend
Sharing your Past 1. Social	0	0	0	0	70	95
2. Academic	10	10	50	10	90	100
3. Professional	10	10	10	20	70	100
4. Relationships	0	0	0	0	50	100
5. Family	5	5	5	5	20	100
Initiating a conversation with	0	0	10	50	70	100.

VI. EXPRESSION OF SELF

1. **What percentage (0-100%) role do dress/ attire/ clothing play, according to you, in projecting your true self to the outside world?**
   70

2. **Do you believe your dress, textiles you use can be made more useful and helpful in your socialization?**
   ☐ Yes ☐ No ☑ Maybe

3. **Please mention the percentage (0-100) of feelings corresponding to the contexts that may be expressed –**

	Emotions	Office	School	College	Wedding	Park	Commuting (Bus, Train)
1	Joy	0	20	70	50	40	0
2	Trust	0	10	80	70	20	0
3	Optimism	0	70	80	70	50	20
4	Love	0	0	50	0	0	0
5	Vigilance	0	70	20	40	60	30
6	Admiration	0	10	40	80	50	0
7	Surprise	50	30	80	20	6	0
8	Fear	0	0	0	0	30	70
9	Pensive	20	30	40	60	0	0
10	Remorse	0	30	30	30	0	0
11	Annoyance	0	40	50	15	0	50
12	Aggression	70	10	70	30	0	20

Annexure 6: Experiment preliminary to Experimental Evaluation 1

Annexure 6a: Purpose of the preliminary Experiment

Aims at evaluation of LED embedded scarf 1 designed as prototype 1. This was a preliminary study to see the response following which a comparative evaluation of three LED embedded scarves was done with few modifications in the questionnaire used for preliminary evaluation. The study lead to proposition of a measure of non-verbal communication with LED embedded scarves in the social context of respondents and a model for non-verbal expression using LED embedded scarves in the social context of respondents, which was consolidated as a result of Experimental Study 1.

Annexure 6b: Participants and sample size for Preliminary Experiment

Total 42 female respondents studying in a national technical institution situated in the North East of India took part in the preliminary evaluation of prototype scarf 1. It was carried out in groups of 2-3, where 33 wearers and 9 viewers were involved. 64% belong to urban and 36% belong to semi-urban background studying at graduate and post-graduate level. Mean age of participants = 24.7 years and Standard Deviation = 3.22 years.

Annexure 6c: Preliminary Experiment Design

Four parameters were evaluated Emotions evoked, Non-verbal Communication, Technology Acceptance model and Usability (5Es) as will be reported further. 5 pairs of emotions from Plutchik's Wheel (1980), (Happiness-Sadness, Optimism-Pessimism, Awesomeness-Boring, Interesting-Annoying and Admirable-Disgusting) were rated on a 9-point semantic differential scale. 7 questions on measurement of Non-verbal communication (Goleman, 2008) was rated on a five-point semantic differential scale (disagree-agree). 5Es of Usability (Quesenbery, 2004 and Yammiyavar, 2005) was rated on a 5-point Likert scale (Very low-Very high) – Efficiency (Effort and time taken); Effectiveness (Understand-ability, Ease of Understanding); Engaging (Likability, Convenience, Aesthetics, Comfort); Learnability (Comprehension, Consistency, Learnability); and Errors made. Technology Acceptance Model (Davis, 1989) with six parameters each of Perceived Ease of Use and Perceived Usefulness were rated on a 7-point Likert scale. Perceived Usefulness comprises – Quicker communication, Improved communication, Improved productivity, Effective communication, Easy communication and Useful for communication. Perceived Ease of Use comprises – Learning is easy, Easy for communication, Clear and understandable, Flexible to interact, Easy to become skill-ful and Easy to use. Communication here refers to non-verbal communication using the LED embedded scarves in the given hypothetical scenarios. Meanings of colors that the scarf could convey were also listed by the respondents in a descriptive section.

Annexure 6d: Experimental Set-up for Preliminary Experiment

The experiment was conducted in an enclosed space with the questionnaire kept on a table and the administrator and respondent seated adjacent or opposite to each other (Figure 6a). The participants were briefed with the objectives of the experiment and after their consent the questionnaire was administered to them. The participants first interacted with the LED embedded scarf 1 (Figure 6b) as described in following subsection of experimental procedure and then recorded their response in the questionnaire provided.

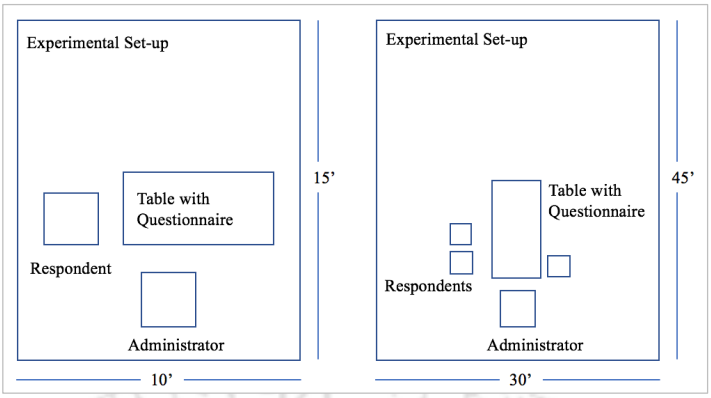


Figure 6a: Experimental Set-up for conducting preliminary Experiment

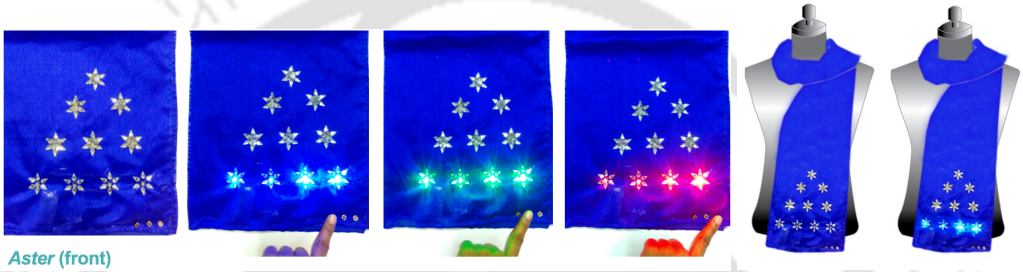


Figure 6b: Tool – LED embedded scarf, Prototype 1 – for conducting preliminary Experiment

Annexure 6e: Experimental Procedure for Preliminary Experiment

33 wearers and 9 viewers took part in an interactive session in groups of 2- 3, where they were asked to imagine being in any one or more of the scenarios, such as travelling alone in a metro, bus stops, college library, strolling in a park, etc. The respondents then communicated meanings through colours of Prototype 1. The study captured the experience and functionality of Prototype 1, when it changes its colours to express certain additional meanings, such as RED glow could mean *I am not comfortable, stop, do not approach, please leave, I am not interested, I am angry, I disagree,* etc. BLUE glow could mean *I am slightly comfortable, I am slightly approachable, I am slightly interested, I am not very pleased, I slightly disagree,* etc. While a GREEN glow could mean *I am comfortable, welcome, one may approach, one may stay, I am interested, I am pleased, I agree*, etc. The wearer had to express themselves while the viewer had to understand the meaning being conveyed by the three colors in any of the scenario or social context, being enacted.

For instance, If the wearer and the viewer are in a hypothetical scenario of an office, Wearer expresses as Red, then the viewer understands that the person is busy. If the wearer and viewer are in a hypothetical scenario of commuting in a bus, Wearer expresses as Red, then the viewer understands that the person is not comfortable. Another example enacted was, the wearer and the viewer are in a hypothetical scenario of a college cafeteria or Library, Wearer expresses as Green, then the viewer understands that the wearer is comfortable or approachable. The responses were marked by the respondents to what degree of expression or understanding took place between them while interacting. Figure 6c depict participants of the preliminary Experiment. There were certain times when participants could not remember the color and the respective meaning and did not understand the message, were slow in understanding – this was considered by them while marking their response for errors made while interacting.

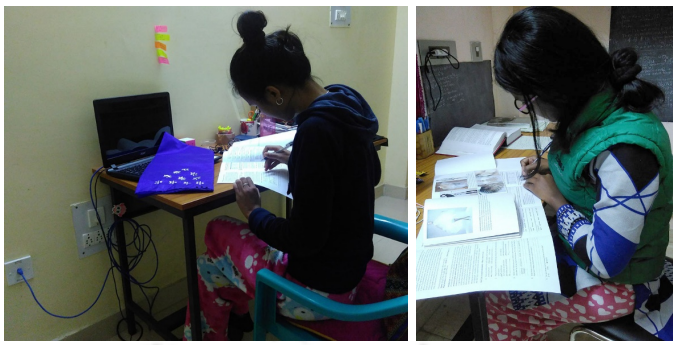


Figure 6c: Participants of Experimental study 1

Annexure 6f: Analysis of results for Preliminary Experiment

Descriptive statistics were used to analyse the results. Reliability of all questions was checked on IBM SPSS Cronbach's Alpha. Principal Component Analysis was used to evaluate if the seven questions for measuring Non-verbal communication were loading together. 4 objectives were analysed through the preliminary experiment which will be described further.

Annexure 6g: Emotions

Emotions rated on a 9 point SD scale with 5 opposite pairs, revealed high positive emotions evoked in the respondents. It was also found after mean comparison that there was no significant difference in emotions evoked between static and dynamic *Aster*. Descriptive statistics was used for analysis as mentioned in Table 6a. Reliability test α=0.967.

Objective 1: To study the effect of emotions evoked by LED embedded scarf 1, a traditionally crafted textile wearable, among users.

Table 6a: Emotion evoked by static and dynamic Aster among respondents

		Happy	Optimistic	Awesome	Interesting	Admirable
Static	Mean	7.60	7.69	7.52	7.69	7.64
	SD	1.289	1.370	1.565	1.456	1.411
Dynamic	Mean	7.88	7.74	7.81	7.98	8.05
	SD	1.797	1.875	1.966	1.841	1.821
Total	Mean	7.74	7.71	7.67	7.83	7.85
	SD	1.561	1.632	1.772	1.656	1.632

Annexure 6h: Non-verbal communication

To understand non-verbal expression pertaining to the usage of *Aster*, respondents were asked if *Aster* could create a better understanding and decorum through a visual language. If they could understand feelings of other people through *Aster* nonverbally. If *Aster* lets them interact non-verbally in a smooth and socially dignified manner. If their personality is being expressed effectively through *Aster*. If symbolic messages are sent visually, could *Aster* modify the outcome of people's behaviour around. And, if colours could create a visual language for communication. A five point SD scale was used to mark their response. The results revealed positive response with respect to the above questions asked the users and that it enhanced their self-expression in a social space by subtle

yet explicit communication. The descriptive statistics is mentioned in Table 6b. Principal Component analysis conducted on SPSS revealed that the 7 variables of non-verbal communication with 6 variables of perceived usefulness and perceived ease of use of Technology Acceptance Model measured social intelligence accurately, as mentioned in Table 6c pattern matrix. KMO test for sampling adequacy value=0.844 and 0.938. Bartlett's correlation test significance value, p=0.00. 2 components were extracted based on Eigen values and variance was 57% and 60%. Component correlation was 0.526 and 0.515. Reliability test α=0.881. These 7 variables were tested again during experimental study 1 with comparative evaluation for 3 LED embedded scarves.

Objective 2: To probe if, LED embedded scarf 1, traditionally crafted textile wearable, enhances non-verbal self-expression for smooth interaction among users while maintaining a decorum in the social space.

Table 6b: Social Intelligence (variables measuring NVC/SI)

Factors	Mean	Median	Mode	SD
Decorum	3.88	4.00	4	1.173
Understand feelings of others	3.79	4.00	5	1.298
You hear better	3.67	4.00	4	1.337
Smooth interaction	3.52	4.00	5	1.486
Express personality effectively	3.43	4.00	4	1.291
Influence Behaviour	3.90	4.00	5	1.265
Colours for communication	4.14	5.00	5	1.260

Table 6c: Pattern matrix of Principal Component Analysis of NVC with PU and PEOU

Pattern Matrix SI-PU			Pattern Matrix SI-PEOU		
	Component			Component	
	1	2		1	2
SI 1	.051	.769	SI 1	.127	.730
SI 2	-.197	.906	SI 2	-.080	.844
SI 3	-.019	.869	SI 3	.205	.711
SI 4	.125	.712	SI 4	.108	.737
SI 5	.027	.726	SI 5	-.135	.871
SI 6	.245	.487	SI 6	.515	.253
SI 7	.336	.552	SI 7	.460	.450
PU 1	.938	-.122	PEOU 1	1.000	-.157
PU 2	.868	.101	PEOU 2	.896	.070
PU 3	.924	-.022	PEOU 3	.973	-.086
PU 4	.948	-.014	PEOU 4	.950	-.006
PU 5	.900	.102	PEOU 5	.932	.039
PU 6	.855	.151	PEOU 6	.817	.179

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Annexure 6i: Usability Analysis

Usability analysis (Table 6d) revealed that *Efficiency, Effectiveness, Engagement* and *Easy learnability* were moderately high and *Error made* is moderately low. The response indicates scope for improving *Aster's* interaction with the user and iterating methods of changing visual cues for much easier operation. Few respondents mentioned that using the product for a considerable time would improve usability, for first time use, understanding the functionality and meaning could be slightly difficult. The usability analysis was carried out for the following five E's – (i) Efficiency (effort and time taken to understand visual cues); (ii) Effectiveness (visual cues were understandable and easy to understand); (iii) Engagement (likability, convenience, aesthetics and comfort); (iv)

Easy learnability (comprehension, consistency, learning to interact); and, (v) Errors made while interacting. Reliability test α=0.840.

Objective 3: To analyse Usability of LED embedded scarf 1, traditionally crafted textile wearable, i.e., Efficiency, Effectiveness, Engagement and Easy learnability, among users for non-verbal expression.

Table 6d: Usability Analysis for interaction with Aster – 42 respondents

	Factors	Mean	Median	Mode	SD
Efficiency	Effort	2.26	2	2	1.106
	Time for cues	2.31	2	2	1.158
Effectiveness	Cues understandable	3.57	4	2	1.291
	Understanding cues easy	3.60	4	5	1.345
Engaging	Likability of Aster	3.48	4	5	1.292
	Convenience	3.62	4	5	1.229
	Aesthetics	3.52	4	5	1.234
	Comfort of interaction	3.55	4	4	1.194
Easy learnability	Comprehension	3.55	4	5	1.194
	Consistency	3.64	4	3	1.055
	Learnability	3.67	4	5	1.282
Error	Errors made	2.43	2	2	1.107

Annexure 6j: Technology Acceptance Model

Response revealed high acceptance towards Aster rated on a Likert scale for perceived ease of us and perceived usefulness. Factors rated for perceived usefulness were – (i) If *Aster* enables quicker non-verbal communication, (ii) If *Aster* improves communication; (iii) If Aster improved productivity; (iv) If *Aster* enabled effective communication; (v) If *Aster* enabled easier non-verbal communication; and, (vi) If *Aster* was useful for non-verbal communication. Factors rated for perceived ease of use were – (i) Learning to operate *Aster* was easy; (ii) *Aster* was easy for non-verbal communication; (iii) Interaction with *Aster* was easy and understandable; (iv) If *Aster* easy to interact with; (v) If it would be easy to become skill-ful in using *Aster*; and, (vi) If *Aster* was easy to use. Descriptive statistics was used for analysis. Principal component analysis with respect to NVC was carried out as described in Table 6c. Descriptive statistics for TAM has been mentioned in Table 6e. Reliability test α=0.96.

Objective 4: To study technology acceptance, i.e., perceived usefulness and perceived ease of use, among users for non-verbal expression of LED embedded scarf 1, a traditionally crafted textile wearable.

Table 6e: TAM descriptive statistics

Factors	Mean	Median	Mode	SD
Quicker communication	5.24	6.00	7	1.819
Improved communication	4.88	5.00	7	1.877
Improved productivity	4.90	5.00	6	1.708
Effective communication	5.14	5.00	7	1.676
Easy communication	5.21	5.50	7	1.774
Useful for communication	5.00	5.00	7	1.861
Learning is easy	5.33	6	6	1.663
Easy for communication	4.93	5	6	1.813
Clear and understandable	5.14	6	7	1.983
Flexible to interact	5.21	6	7	1.828
Easy to become skill-ful	5.33	6	7	1.817
Easy to use	5.24	6	7	1.805

Annexure 6k: Color meanings given by respondents

The choice was given to the users to represent colours through meanings according to them for a colour changing textile. The response has been tabulated in Table 6f. The number within brackets next to the terms is the word count for that term.

Table 6f: Colour meaning given by the respondents

Colour	Meaning
Red	Happy, Excited
	Angry (9), Uncomfortable (6), Disagreement (5), Danger (2), No (2), Not interested (2), Stop, Aversion, Don't want to be approached, Scared, Go away
Blue	Calm (3), Cool, Chill, Normal, Confidence, Optimistic, Peaceful
	Neutral (4), Doubtful (3), Slightly disagree, Don't want to express, Only if it is important, Slightly comfortable, Nervous, Scared, Feeling low, Negative, Slightly agree, Slightly comfortable, Sceptical, Sad
Green	Agree (5), Happy (5), Comfortable (4), Yes (3), Permission granted, Interested, Approachable, Need Privacy, Welcoming, Ready to go, Open to next move, Very interested, Fine, Neutral
	Jealous (2), Sick, Sad
Colour 4	Pink (2) – Happiness Yellow (9) – Happy (3), Positive, Doubtful White/colourless-danger
Colour 5	Purple Orange Navy Blue–Discuss any subject Black – Mourning
Colour 6	Orange – Need leisure/Want to hang out, White Pink

Annexure 6l: Refining tentative model for Non-verbal Communication

Attributes of negative emotions and aesthetics were added from exploratory study 1 to the NVC model for experimental study 1 for evaluation and validation of correlations between the factors mentioned in posited NVC model Figure 6d. The 4 factors of Social intelligence (NVC), Positive emotions, Negative emotions and Aesthetics were thus evaluated through experimental study 1 for correlational significance with respect to perceived usefulness and perceived ease of use of technology acceptance model which leads to actual system usage, as described in Figure 6e.

Annexure 6m: Outcome of the preliminary Experiment which was taken further for Experimental Study 1

SD scale for emotions was reverted to a 5-point Likert scale for measurement of positive and negative emotions evoked by digital craft prototypes. Attributes of Aesthetics were added to contribute to the theoretical model. The theoretical model was refined to depict correlatins between 5 positive emotions, 5 negative emotions, 5 attributes of aesthetics, 7 attributes measuring non-verbal expression through digital crafts with respect to 6 variables each measuring perceived ease of use and perceived usefulness (Davis, 1989) that determines the acceptance of digital crafts by respondents. System Usability Scale was used for Experimental Study 1 instead of 5E's of Usability as in the preliminary experiment.

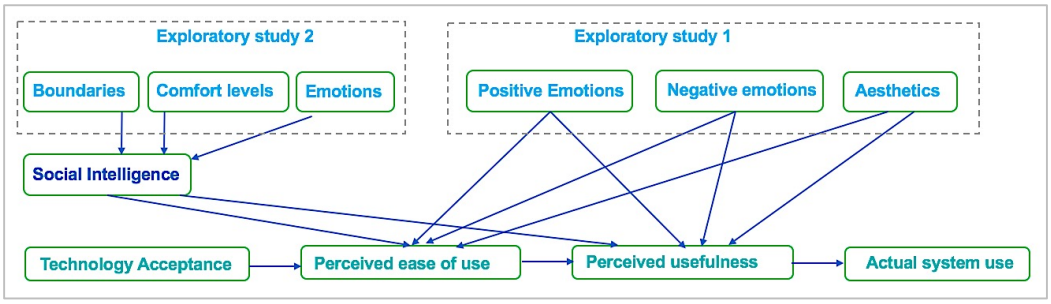


Figure 6d: Refined posited model for non-verbal communication with textile wearables

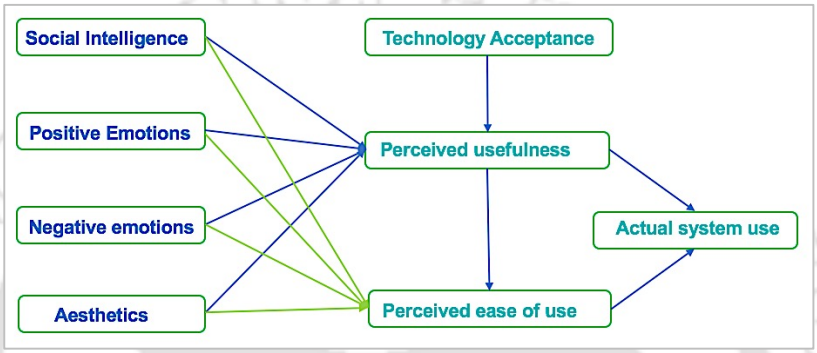


Figure 6e: Posited model for non-verbal communication with textile wearables for evaluation in Experimental study 1

Annexure 7: Un-Filled Questionnaire – Experimental Study 1

IITG/DoD/UE Lab January 2018/ Informed consent

The UE Lab at IITG is conducting experiments and collecting data from users as part of its ongoing projects and research work. The lab will record your participation in experiments and collect data using techniques such as interviews, videotapes, digital capture, etc. Information and data collected is likely to be used as part of published papers, reports and presentations in academics. However, no personal information that identifies you will be publicly published. Only collated results in the form of statistics will be published. Your participation is voluntary.
Should you have any question on your participation/ experiment/ our researchers will be glad to answer them and address your concerns. We **thank you** for your time, enthusiasm and contribution to scientific research in India.

Please enter the following details about yourself –

Name: ..... **Age:** ..... **Gender:** ..... **Place of Origin:** .....
Marital Status: Married/Unmarried **Department/Year:** .....
Room No.: .....

Introduction: Through this questionnaire, the researchers are trying to understand perceptions (likes, dislikes, attitude) of young users about three hand embroidered digital scarves comprising embedded electronics - *Aster*, *Iris* and *Nymphaea* - and how well could it be used to communicate NON-VERBALLY in scenarios such as traveling in a metro, café, airport, office, college, etc.
An example of the functionality could be, when *scarves* glow Red it could mean 'do not approach', 'discomfort', 'I am not interested', 'I am angry', 'I disagree,' etc; If *scarves* glow BLUE/YELLOW it could mean you are 'slightly skeptical', 'cautious or doubtful', 'you slightly refrain from being approached', or 'you are jittery'; and if scarves glow GREEN, you could signal 'you may be approached', or 'you are comfortable', and so on. The cues are meant for subtle expression instead of verbal communication in situations where unexpressed needs/views/ opinions need to be expressed but not explicitly.
For example if strangers come too close while commuting, when in danger the information gets transmitted wirelessly to get help at the earliest, in a meeting for votes, in an office cubicle to denote availability or opinion, etc. The visual cues maybe expressed only when needed, otherwise they remain an embellishment neatly integrated with the textile.
Aster comprises LEDs amidst petals and sequins, *Iris* is LEDs embedded within *Kantha* embroidery and *Nymphaea* is a *Madhubani* painted textile with LEDs controlled with three buttons placed at the corner of the scarves. This is an initial study with basic functions integrated with the textile prototype to understand how users would perceive E-textiles.

Pertaining to *ASTER* (Petal-sequins embroidered scarf)

PART 1: Please tick the emotions, aesthetic appeal and attitude associated with *Aster* when LIT UP in the tables below, 1 is least and 5 is highest score.

EMOTIONS	1	2	3	4	5
Happy					
Optimistic					
Awesome					
Interesting					
Admirable					
Sad					
Pessimistic					
Boring					
Annoying					
Disgusting					

AESTHETICS	1	2	3	4	5
Attractive					
Desirable					
Beautiful					
Pleasing					
Enjoyable					
Shapes					
Color					
Texture					
Dullness					
Simplicity					

PART 2: Understanding social intelligence pertaining to the usage of *Aster* in the given scenarios –

1. Do you think that *Aster* can create a dignified decorum by letting you understand the visual language of changing colors, thus create a better understanding among the people around non-verbally?
   O Agree O Slightly agree O Neutral O Slightly disagree O Disagree
2. Do you think you were able to understand wearer's feelings, non-verbally better with *Aster* if not necessarily put in words?
   O Agree O Slightly agree O Neutral O Slightly disagree O Disagree
3. Do you think you could *hear* or *feel* the wearer's feelings, non-verbally through *Aster*?
   O Agree O Slightly agree O Neutral O Slightly disagree O Disagree
4. Do you think that using *Aster* is letting interaction among people around you happen smoothly and socially dignified (within social norms)?
   O Agree O Slightly agree O Neutral O Slightly disagree O Disagree
5. Do you think that *Aster* lets wearer express his/her personality effectively?
   O Agree O Slightly agree O Neutral O Slightly disagree O Disagree

Annexure 7: Un-Filled Questionnaire – Experimental Study 1 – Page 1-2

6. Do you think *Aster* can modify/influence the outcome of people's behavior around the wearer, if symbolic messages are sent visually?

O Agree O Slightly agree O Neutral O Slightly disagree O Disagree

7. Do you believe colors could be used as signals to communicate and interpret feelings and make people around act accordingly?

O Agree O Slightly agree O Neutral O Slightly disagree O Disagree

Part 3: Technology Acceptance Model – Analyzing acceptance of *Aster* among the users. Please tick appropriate cells below, 1 is least likely and 7 is most likely, for non-verbal communication –

Perceived Usefulness	1	2	3	4	5	6	7
Aster could enable quick communication							
Aster could improve the process of communication							
Aster improved the productivity of communication							
Aster could enable effective communication							
Aster could enable easier communication							
I found *Aster* useful for communication							
Perceived Ease of Use							
Learning to understand *Aster* is easy for me							
I find *Aster* easy to use for communicating							
My interaction with *Aster* is clear and understandable							
I find *Aster* to be flexible to interact with							
It is easy for me to become skillful at using *Aster*							
I find *Aster* easy to be used							

PART 4: Did you feel stressed at any point while interacting with *Aster*, Please circle appropriate units below, very low to very high –

1. How much thinking, deciding, searching, calculating was required?

VERY LOW VERY HIGH

2. How much of body movement, push, pull, activate, control, etc. was required?

VERY LOW VERY HIGH

3. How much of time pressure did you feel due to the pace at which the interactions occurred?

VERY LOW VERY HIGH

4. How hard did you have to work (mentally and physically) to complete the task?

VERY LOW VERY HIGH

5. How successful and satisfied were you while communicating with *Aster*?

VERY LOW VERY HIGH

6. How insecure, discouraged, irritated, stressed and annoyed were you while communicating with it?

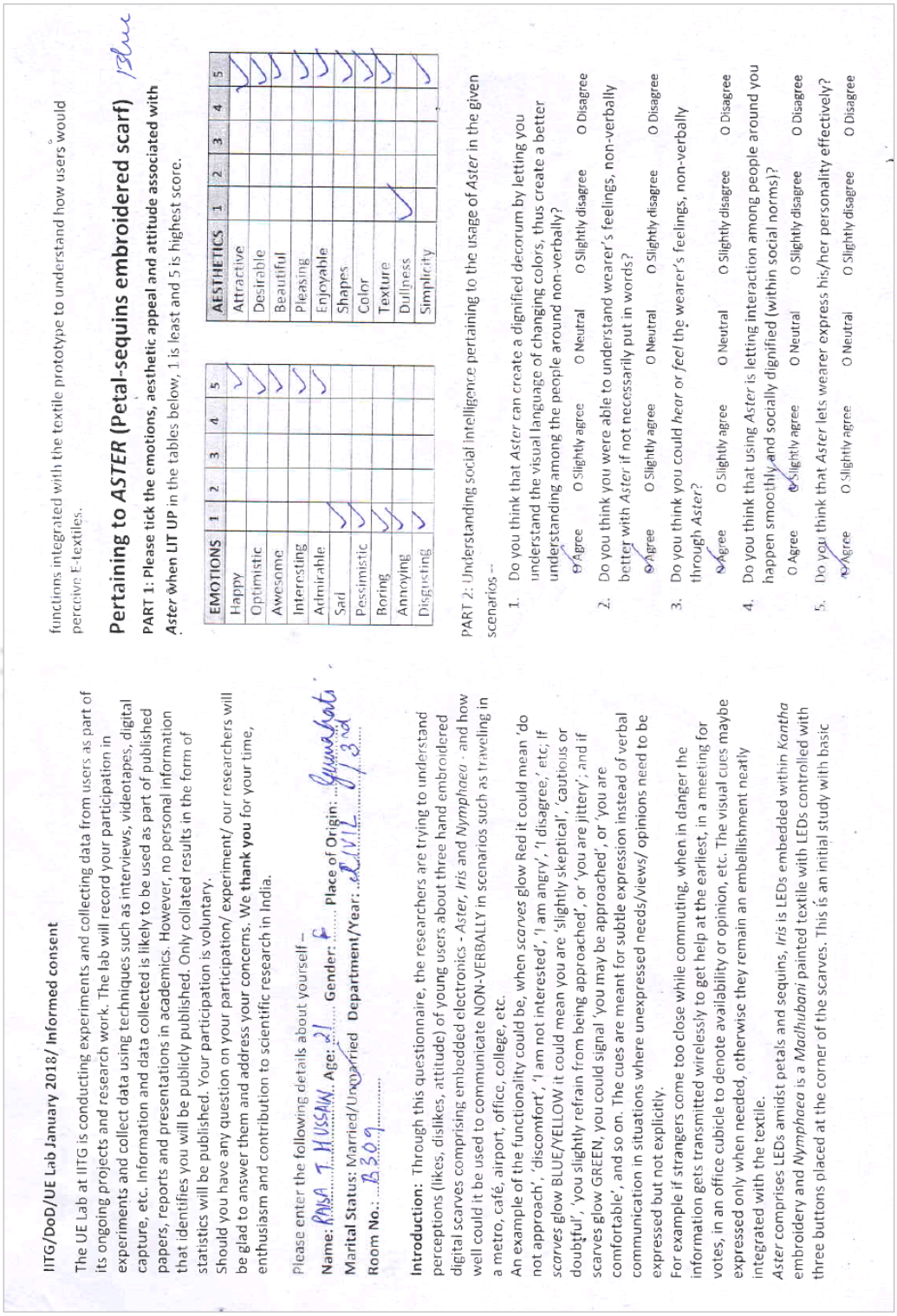
VERY LOW VERY HIGH

Part 5: System Usability Scale - After using *Aster* for the scenarios as specified above, please tick appropriate cells below to convey how efficient, effective, engaging, easy to learn and error tolerant the experience of using *Aster* for communicating through visual cues was to yourself; **1 is *low*** and 5 is ***high***.

	Usability factors	1	2	3	4	5
1	I think I would like to use *Aster* frequently					
2	I found *Aster* unnecessarily complex					
3	I thought *Aster* was easy to use					
4	I think I would need support of technical person to be able to use it					
5	I found the functions were well integrated					
6	I found there was too much inconsistency					
7	I imagine most people would find it easy to learn how to use *Aster*					
8	I found *Aster* very cumbersome to use					
9	I felt confident while using *Aster*					
10	I needed to learn a lot before I could get going with *Aster*					

Annexure 7: Un-Filled Questionnaire – Experimental Study 1 – Page 3-4. The same questions were asked for Prototype scarf 2 and 3.

Annexure 8: Filled Questionnaire – Experimental Study 1



IITG/DoD/UE Lab January 2018/ Informed consent

The UE Lab at IITG is conducting experiments and collecting data from users as part of its ongoing projects and research work. The lab will record your participation in experiments and collect data using techniques such as interviews, videotapes, digital capture, etc. Information and data collected is likely to be used as part of published papers, reports and presentations in academics. However, no personal information that identifies you will be publicly published. Only collated results in the form of statistics will be published. Your participation is voluntary.
Should you have any question on your participation/ experiment/ our researchers will be glad to answer them and address your concerns. We **thank you** for your time, enthusiasm and contribution to scientific research in India.

Please enter the following details about yourself –
Name: RIYA T. HUSAIN **Age:** 21 **Gender:** F **Place of Origin:** Ahmedabad
Marital Status: Married/Unmarried **Department/Year:** UCEVIL / 3rd
Room No.: B309

Introduction: Through this questionnaire, the researchers are trying to understand perceptions (likes, dislikes, attitude) of young users about three hand embroidered digital scarves comprising embedded electronics - *Aster*, *Iris* and *Nymphaea* - and how well could it be used to communicate NON-VERBALLY in scenarios such as traveling in a metro, café, airport, office, college, etc.
An example of the functionality could be, when *scarves* glow Red it could mean 'do not approach', 'discomfort', 'I am not interested', 'I am angry', 'I disagree,' etc, if *scarves* glow BLUE/YELLOW it could mean you are 'slightly skeptical', 'cautious or doubtful', 'you slightly refrain from being approached', or 'you are jittery'; and if scarves glow GREEN, you could signal 'you may be approached', or 'you are comfortable', and so on. The cues are meant for subtle expression instead of verbal communication in situations where unexpressed needs/views/ opinions need to be expressed but not explicitly.
For example if strangers come too close while commuting, when in danger the information gets transmitted wirelessly to get help at the earliest, in a meeting for votes, in an office cubicle to denote availability or opinion, etc. The visual cues maybe expressed only when needed, otherwise they remain an embellishment neatly integrated with the textile.
Aster comprises LEDs amidst petals and sequins, *Iris* is LEDs embedded within *Kantha* embroidery and *Nymphaea* is a *Madhubani* painted textile with LEDs controlled with three buttons placed at the corner of the scarves. This is an initial study with basic functions integrated with the textile prototype to understand how users would perceive E-textiles.

Pertaining to *ASTER* (Petal-sequins embroidered scarf) Blue

PART 1: Please tick the emotions, aesthetic appeal and attitude associated with *Aster* when LIT UP in the tables below, 1 is least and 5 is highest score.

EMOTIONS	1	2	3	4	5
Happy					✓
Optimistic				✓	
Awesome				✓	
Interesting				✓	
Admirable				✓	
Sad		✓			
Pessimistic		✓			
Boring		✓			
Annoying		✓			
Disgusting		✓			

AESTHETICS	1	2	3	4	5
Attractive					✓
Desirable					✓
Beautiful					✓
Pleasing					✓
Enjoyable					✓
Shapes					✓
Color					✓
Texture					✓
Dullness			✓		
Simplicity			✓		

PART 2: Understanding social intelligence pertaining to the usage of *Aster* in the given scenarios –

1. Do you think that *Aster* can create a dignified decorum by letting you understand the visual language of changing colors, thus create a better understanding among the people around non-verbally?
   ✓ Agree O Slightly agree O Neutral O Slightly disagree O Disagree
2. Do you think you were able to understand wearer's feelings, non-verbally better with *Aster* if not necessarily put in words?
   ✓ Agree O Slightly agree O Neutral O Slightly disagree O Disagree
3. Do you think you could *hear* or *feel* the wearer's feelings, non-verbally through *Aster*?
   ✓ Agree O Slightly agree O Neutral O Slightly disagree O Disagree
4. Do you think that using *Aster* is letting interaction among people around you happen smoothly and socially dignified (within social norms)?
   O Agree ✓ Slightly agree O Neutral O Slightly disagree O Disagree
5. Do you think that *Aster* lets wearer express his/her personality effectively?
   ✓ Agree O Slightly agree O Neutral O Slightly disagree O Disagree

Annexure 8: Filled Questionnaire – Experimental Study 1 – Page 1-2

6. Do you think *Aster* can modify/influence the outcome of people's behavior around the wearer, if symbolic messages are sent visually?
O Agree O Slightly agree O Neutral O Slightly disagree O Disagree

7. Do you believe colors could be used as signals to communicate and interpret feelings and make people around act accordingly?
O Agree O Slightly agree O Neutral O Slightly disagree O Disagree

Part 3: Technology Acceptance Model – Analyzing acceptance of *Aster* among the users. Please tick appropriate cells below, 1 is least likely and 7 is most likely, for non-verbal communication –

	1	2	3	4	5	6	7
Perceived Usefulness							
Aster could enable quick communication							✓
Aster could improve the process of communication							✓
Aster improved the productivity of communication							✓
Aster could enable effective communication							✓
Aster could enable easier communication							✓
I found *Aster* useful for communication							✓
Perceived Ease of Use							
Learning to understand *Aster* is easy for me							✓
I find *Aster* easy to use for communicating							✓
My interaction with *Aster* is clear and understandable						✓	
I find *Aster* to be flexible to interact with						✓	
It is easy for me to become skillful at using *Aster*						✓	
I find *Aster* easy to be used						✓	

PART 4: Did you feel stressed at any point while interacting with *Aster*, Please circle appropriate units below, very low to very high –

1. How much thinking, deciding, searching, calculating was required?
VERY LOW ✓ VERY HIGH

2. How much of body movement, push, pull, activate, control, etc. was required?
VERY LOW ✓ VERY HIGH

3. How much of time pressure did you feel due to the pace at which the interactions occurred?
VERY LOW ✓ VERY HIGH

4. How hard did you have to work (mentally and physically) to complete the task?
VERY LOW ✓ VERY HIGH

5. How successful and satisfied were you while communicating with *Aster*?
VERY LOW ✓ VERY HIGH

6. How insecure, discouraged, irritated, stressed and annoyed were you while communicating with it?
VERY LOW ✓ VERY HIGH

Part 5: System Usability Scale - After using *Aster* for the scenarios as specified above, please tick appropriate cells below to convey how efficient, effective, engaging, easy to learn and error tolerant the experience of using *Aster* for communicating through visual cues was to yourself; **1 is *low*** and 5 is ***high***.

	Usability factors	1	2	3	4	5
1	I think I would like to use *Aster* frequently					✓
2	I found *Aster* unnecessarily complex			✓		
3	I thought *Aster* was easy to use					✓
4	I think I would need support of technical person to be able to use it			✓		
5	I found the functions were well integrated				✓	
6	I found there was too much inconsistency			✓		
7	I imagine most people would find it easy to learn how to use *Aster*					✓
8	I found *Aster* very cumbersome to use			✓		
9	I felt confident while using *Aster*					✓
10	I needed to learn a lot before I could get going with *Aster*			✓		

Annexure 8: Filled Questionnaire – Experimental Study 1 – Page 3-4

Annexure 9: Un-Filled Questionnaire – Experimental Study 2

IITG/DoD/UE Lab/ October 2018/ Informed consent

The UE Lab at IITG is conducting experiments and collecting data from users as part of its ongoing projects and research work. The lab will record your participation in experiments and collect data using techniques such as interviews, videotapes, digital capture, etc. Information and data collected is likely to be used as part of published papers, reports and presentations in academics. However, no personal information that identifies you will be publicly published. Only collated results in the form of statistics will be published. Your participation is voluntary. Should you have any question on your participation/ experiment/ our researchers will be glad to answer them and address your concerns. We thank you for your time, enthusiasm and contribution to scientific research in India.

Study Brief: The study aims to collect response of young indian students to a traditional *bundi*/jacket capable of changing visual cues/colors by a remote control. The visual cues enable wearer to express meanings – emotions, feelings to people around in certain contexts allowing non-verbal communiation in situations where words need not be used to express one-self subtly. This capability of textile wearables for non-verbal self-expression is being captured by the experiment being conducted.

Name: ..... Age: ..... Gender: ..... Place of origin: ..... Year, Department: .....

Part A: Please tick the emotions and feelings evoked in you upon viewing/interacting with the static jacket in the table below. For emotions, 1 is least and 5 is the highest score. For feelings, 1= disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree.

Emotions	1 Very low	2 Low	3 Neutral	4 High	5 Very High
Happy					
Optimistic					
Awesome					
Interesting					
Admirable					
Sad					
Pessimistic					
Boring					
Annoying					
Disgusting					
Angry					
Surprised					

Feelings	1 Disagree	2 Slightly Disagree	3 Neutral	4 Slightly agree	5 Agree
I am relaxed					
Leave me alone					
I am waiting for friends to join					
I am thinking deeply					
I'm ok to chat with anyone					
I am angry					
I am in a good mood today					

Part B: Please tick the emotions evoked in you upon viewing/interacting with the LED jacket in the tables below with respect to each of the six colors, 1 is least and 5 is the highest score.

RED color of the jacket					
Emotions	1	2	3	4	5
Happiness					
Optimism					
Awesome					
Interesting					
Admirable					
Sadness					
Pessimism					
Boring					
Annoying					
Disgusting					
Angry					
Surprised					

GREEN color of the jacket					
	1	2	3	4	5
Happiness					
Optimism					
Awesome					
Interesting					
Admirable					
Sadness					
Pessimism					
Boring					
Annoying					
Disgusting					
Angry					
Surprised					

BLUE color of the jacket					
	1	2	3	4	5
Happiness					
Optimism					
Awesome					
Interesting					
Admirable					
Sadness					
Pessimism					
Boring					
Annoying					
Disgusting					
Angry					
Surprised					

TEAL color of the jacket					
	1	2	3	4	5
Happiness					
Optimism					
Awesome					
Interesting					
Admirable					
Sadness					
Pessimism					
Boring					
Annoying					
Disgusting					
Angry					
Surprised					

PURPLE color of the jacket					
	1	2	3	4	5
Happiness					
Optimism					
Awesome					
Interesting					
Admirable					
Sadness					
Pessimism					
Boring					
Annoying					
Disgusting					
Angry					
Surprised					

ORANGE color of the jacket					
	1	2	3	4	5
Happiness					
Optimism					
Awesome					
Interesting					
Admirable					
Sadness					
Pessimism					
Boring					
Annoying					
Disgusting					
Angry					
Surprised					

YELLOW color of the jacket					
	1	2	3	4	5
Happiness					
Optimism					
Awesome					
Interesting					
Admirable					
Sadness					
Pessimism					
Boring					
Annoying					
Disgusting					
Angry					
Surprised					

WHITE color of the jacket					
	1	2	3	4	5
Happiness					
Optimism					
Awesome					
Interesting					
Admirable					
Sadness					
Pessimism					
Boring					
Annoying					
Disgusting					
Angry					
Surprised					

Annexure 9: Un-Filled Questionnaire – Experimental Study 2 – Page 1

Part C1: What do you think the person wearing the jacket, in a casual and relaxed social space of Café Coffee Day, intends to express to people around, please tick all relevant ones from the cells below. 1= disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree.

Feelings / Colors	I am relaxed					Leave me alone					I am waiting for friends to join					I am thinking deeply					I'm ok to chat with anyone					I am angry					I am in a good mood today				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Red																																			
Green																																			
Blue																																			
Teal																																			
Purple																																			
Orange																																			
Yellow																																			
White																																			

Part C2: If you were sitting in a casual and relaxed social space of Café Coffee Day, which colors would you choose to represent the following, please tick the relevant cells below. 1= disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree.

Feelings / Colors	I am relaxed					Leave me alone					I am waiting for friends to join					I am thinking deeply					I'm ok to chat with anyone					I am angry					I am in a good mood today				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Red																																			
Green																																			
Blue																																			
Teal																																			
Purple																																			
Orange																																			
Yellow																																			
White																																			

Part D: System Usability Scale - Please tick appropriate cells below to rate the experience of using the jacket for emotions evoked in you, non-verbal communication and self-expression through visual cues; 1=*low* and 5=*high*.

	Usability factors	1	2	3	4	5
1	I think I would like to use the led jacket frequently					
2	I found the led jacket unnecessarily complex					
3	I thought the led jacket was easy to use					
4	I think I would need support of technical person to be able to use it					
5	I found the functions were well integrated					
6	I found there was too much inconsistency					
7	I imagine most people would find it easy to learn how to use the led jacket					
8	I found the led jacket very cumbersome to use					
9	I felt confident while using the led jacket					
10	I needed to learn a lot before I could get going with the led jacket					

Please write down your views/opinions about the jacket/experiment or any suggestions –

.....

.....

.....

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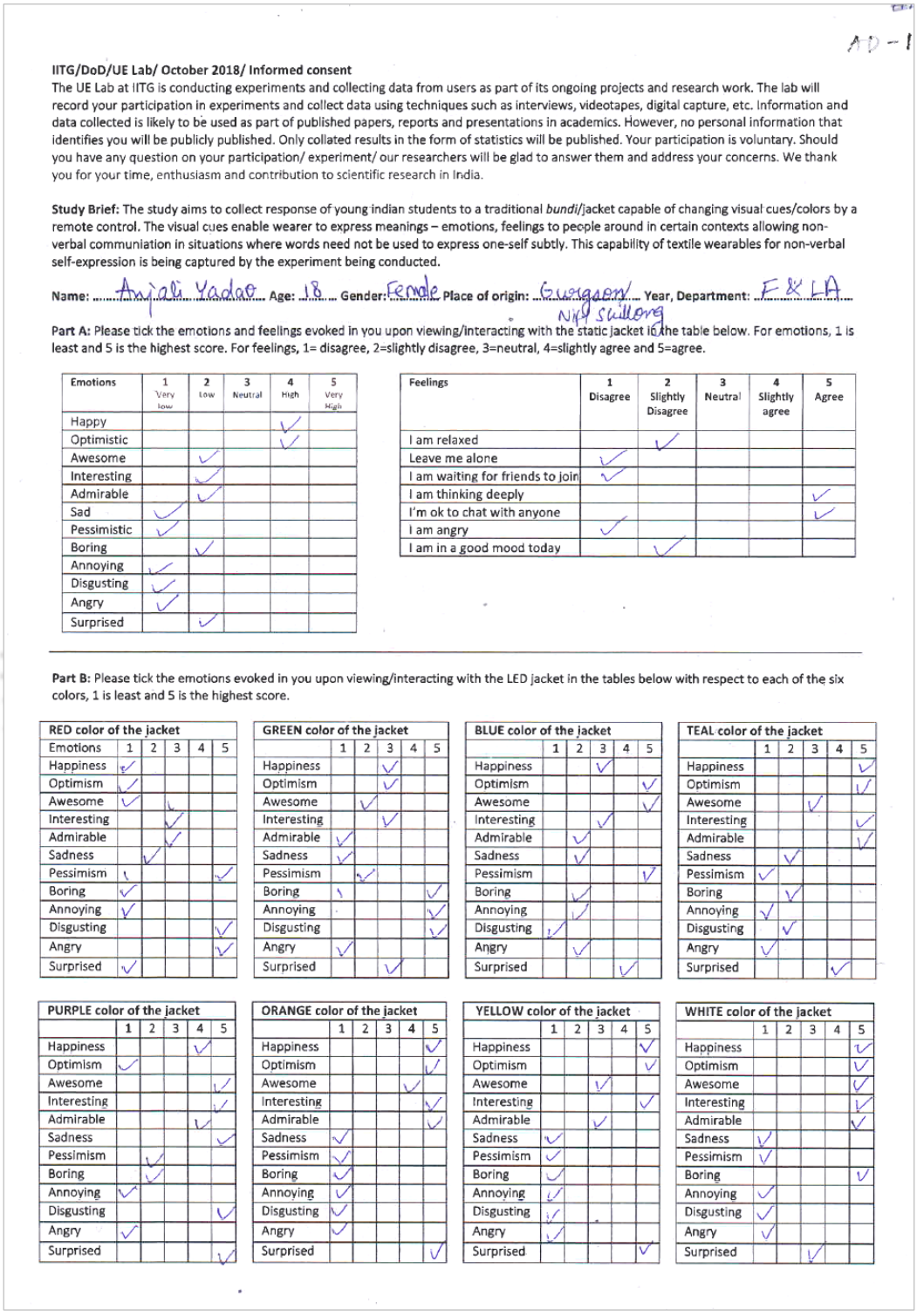
Annexure 9: Un-Filled Questionnaire – Experimental Study 2 – Page 2

Annexure 10: Filled Questionnaire – Experimental Study 2



AD-1

IITG/DoD/UE Lab/ October 2018/ Informed consent

The UE Lab at IITG is conducting experiments and collecting data from users as part of its ongoing projects and research work. The lab will record your participation in experiments and collect data using techniques such as interviews, videotapes, digital capture, etc. Information and data collected is likely to be used as part of published papers, reports and presentations in academics. However, no personal information that identifies you will be publicly published. Only collated results in the form of statistics will be published. Your participation is voluntary. Should you have any question on your participation/ experiment/ our researchers will be glad to answer them and address your concerns. We thank you for your time, enthusiasm and contribution to scientific research in India.

Study Brief: The study aims to collect response of young indian students to a traditional *bundi*/jacket capable of changing visual cues/colors by a remote control. The visual cues enable wearer to express meanings – emotions, feelings to people around in certain contexts allowing non-verbal communiation in situations where words need not be used to express one-self subtly. This capability of textile wearables for non-verbal self-expression is being captured by the experiment being conducted.

Name: Anjali Yadav **Age:** 18 **Gender:** Female **Place of origin:** Gurgaon/ NIFT Shillong **Year, Department:** F & LA

Part A: Please tick the emotions and feelings evoked in you upon viewing/interacting with the static jacket in the table below. For emotions, 1 is least and 5 is the highest score. For feelings, 1= disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree.

Emotions	1 Very low	2 Low	3 Neutral	4 High	5 Very High
Happy				✓	
Optimistic				✓	
Awesome		✓			
Interesting		✓			
Admirable		✓			
Sad	✓				
Pessimistic	✓				
Boring		✓			
Annoying	✓				
Disgusting	✓				
Angry	✓				
Surprised		✓			

Feelings	1 Disagree	2 Slightly Disagree	3 Neutral	4 Slightly agree	5 Agree
I am relaxed		✓			
Leave me alone	✓				
I am waiting for friends to join	✓				
I am thinking deeply					✓
I'm ok to chat with anyone					✓
I am angry	✓				
I am in a good mood today		✓			

Part B: Please tick the emotions evoked in you upon viewing/interacting with the LED jacket in the tables below with respect to each of the six colors, 1 is least and 5 is the highest score.

RED color of the jacket

Emotions	1	2	3	4	5
Happiness	✓				
Optimism	✓				
Awesome	✓				
Interesting			✓		
Admirable			✓		
Sadness		✓			
Pessimism	✓				✓
Boring	✓				
Annoying	✓				
Disgusting					✓
Angry					✓
Surprised	✓				

GREEN color of the jacket

	1	2	3	4	5
Happiness			✓		
Optimism			✓		
Awesome		✓			
Interesting			✓		
Admirable	✓				
Sadness	✓				
Pessimism		✓			
Boring	✓				✓
Annoying					✓
Disgusting					✓
Angry	✓				
Surprised			✓		

BLUE color of the jacket

	1	2	3	4	5
Happiness			✓		
Optimism					✓
Awesome					✓
Interesting			✓		
Admirable		✓			
Sadness		✓			
Pessimism					✓
Boring		✓			
Annoying		✓			
Disgusting	✓				
Angry		✓			
Surprised				✓	

TEAL color of the jacket

	1	2	3	4	5
Happiness					✓
Optimism					✓
Awesome			✓		
Interesting					✓
Admirable					✓
Sadness		✓			
Pessimism	✓				
Boring		✓			
Annoying	✓				
Disgusting		✓			
Angry	✓				
Surprised				✓	

PURPLE color of the jacket

	1	2	3	4	5
Happiness				✓	
Optimism	✓				
Awesome					✓
Interesting					✓
Admirable				✓	
Sadness					✓
Pessimism		✓			
Boring		✓			
Annoying	✓				
Disgusting					✓
Angry	✓				
Surprised					✓

ORANGE color of the jacket

	1	2	3	4	5
Happiness					✓
Optimism					✓
Awesome				✓	
Interesting					✓
Admirable					✓
Sadness	✓				
Pessimism	✓				
Boring	✓				
Annoying	✓				
Disgusting	✓				
Angry	✓				
Surprised					✓

YELLOW color of the jacket

	1	2	3	4	5
Happiness					✓
Optimism					✓
Awesome			✓		
Interesting					✓
Admirable			✓		
Sadness	✓				
Pessimism	✓				
Boring	✓				
Annoying	✓				
Disgusting	✓				
Angry	✓				
Surprised					✓

WHITE color of the jacket

	1	2	3	4	5
Happiness					✓
Optimism					✓
Awesome					✓
Interesting					✓
Admirable					✓
Sadness	✓				
Pessimism	✓				
Boring					✓
Annoying	✓				
Disgusting	✓				
Angry	✓				
Surprised			✓		

Annexure 10: Filled Questionnaire – Experimental Study 2 – Page 1

Part C1: What do you think the person wearing the jacket, in a casual and relaxed social space of Café Coffee Day, intends to express to people around, please tick all relevant ones from the cells below. 1= disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree.

Feelings / Colors	I am relaxed					Leave me alone					I am waiting for friends to join					I am thinking deeply					I'm ok to chat with anyone					I am angry					I am in a good mood today				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Red	✓									✓			✓			✓					✓					✓					✓				
Green					✓	✓									✓				✓					✓								✓			
Blue					✓			✓						✓						✓		✓												✓	
Teal					✓	✓									✓		✓								✓	✓									✓
Purple	✓								✓		✓									✓			✓					✓				✓			
Orange					✓	✓								✓			✓								✓	✓								✓
Yellow					✓			✓					✓						✓					✓		✓								✓
White					✓	✓									✓					✓					✓	✓								✓

Part C2: If you were sitting in a casual and relaxed social space of Café Coffee Day, which colors would you choose to represent the following, please tick the relevant cells below. 1= disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree.

Feelings / Colors	I am relaxed					Leave me alone					I am waiting for friends to join					I am thinking deeply					I'm ok to chat with anyone					I am angry					I am in a good mood today				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Red	✓								✓		✓					✓					✓								✓			✓				
Green				✓								✓							✓			✓					✓					✓			
Blue					✓		✓							✓				✓				✓				✓						✓			
Teal					✓	✓						✓					✓					✓				✓							✓		
Purple			✓						✓			✓								✓	✓						✓					✓			
Orange					✓	✓								✓			✓								✓	✓								✓	
Yellow					✓	✓						✓						✓				✓				✓					✓				
White					✓	✓									✓		✓								✓	✓									✓

Part D: System Usability Scale - Please tick appropriate cells below to rate the experience of using the jacket for emotions evoked in you, non-verbal communication and self-expression through visual cues; 1=*low* and 5=*high*.

	Usability factors	1	2	3	4	5
1	I think I would like to use the led jacket frequently			✓		
2	I found the led jacket unnecessarily complex		✓			
3	I thought the led jacket was easy to use			✓		
4	I think I would need support of technical person to be able to use it	✓				
5	I found the functions were well integrated				✓	
6	I found there was too much inconsistency		✓			
7	I imagine most people would find it easy to learn how to use the led jacket				✓	
8	I found the led jacket very cumbersome to use		✓			
9	I felt confident while using the led jacket	✓				
10	I needed to learn a lot before I could get going with the led jacket	✓				

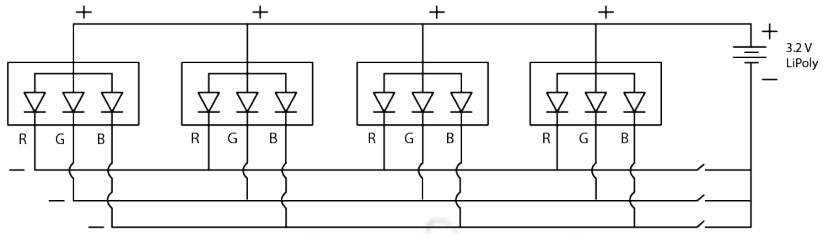
Please write down your views/opinions about the jacket/experiment or any suggestions –

Please tick one – I prefer (a) verbal expression (for), or (b) non-verbal exp (jacket)

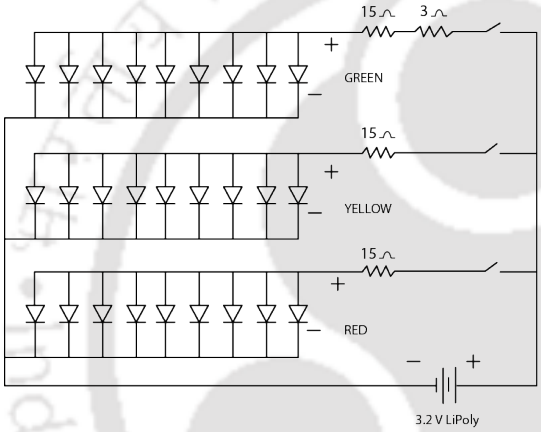
D

Annexure 10: Filled Questionnaire – Experimental Study 2 – Page 2.

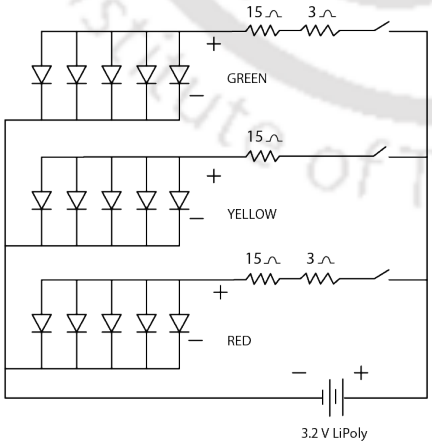
Annexure 11: Electronic Circuit diagram for three LED embedded scarves



Circuit diagram for Prototype scarf 1

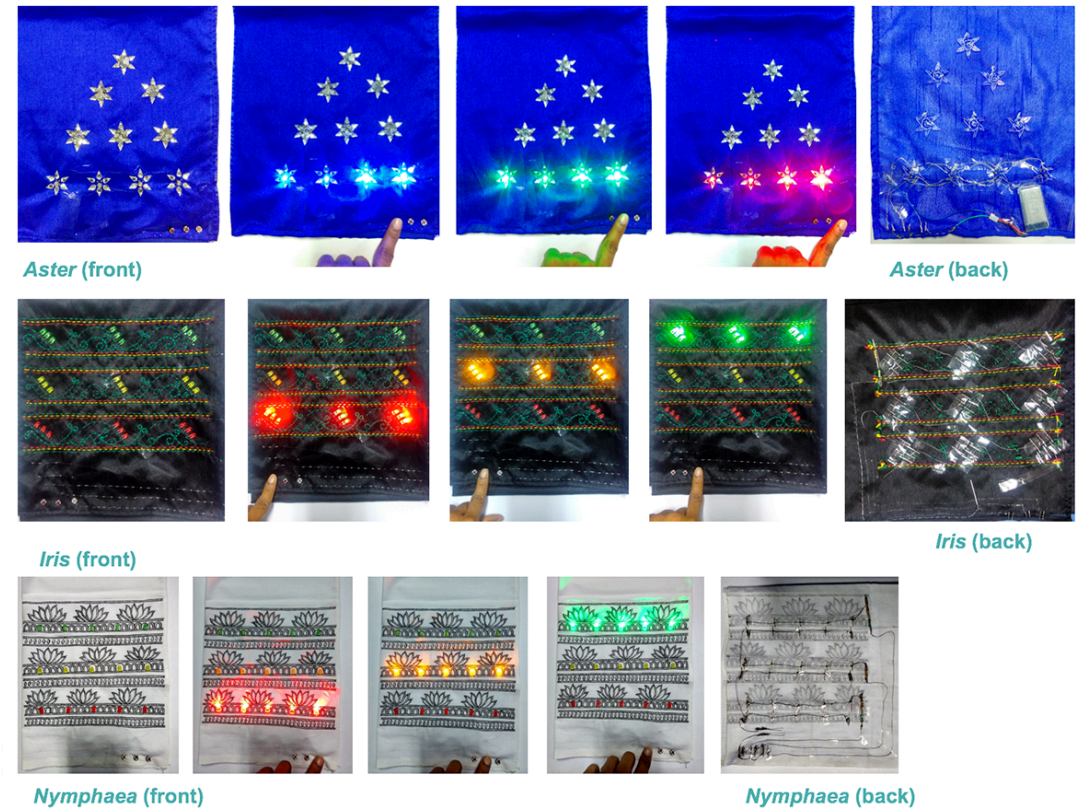


Circuit diagram for Prototype scarf 2

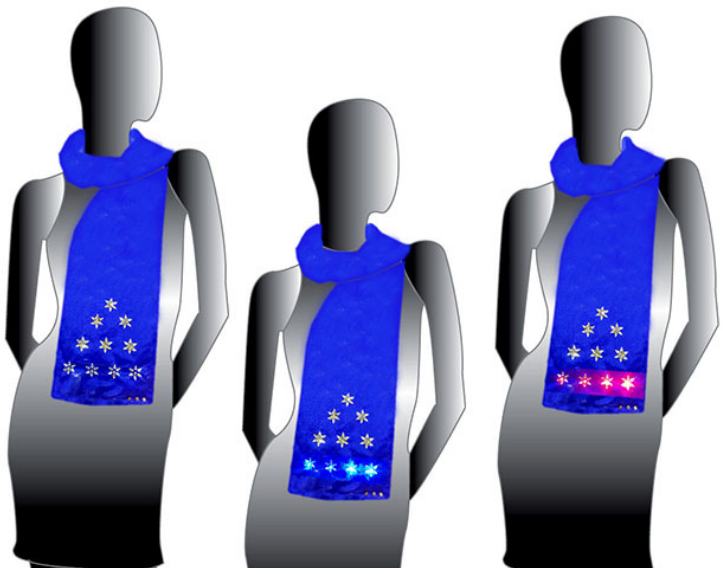


Circuit diagram for Prototype scarf 3

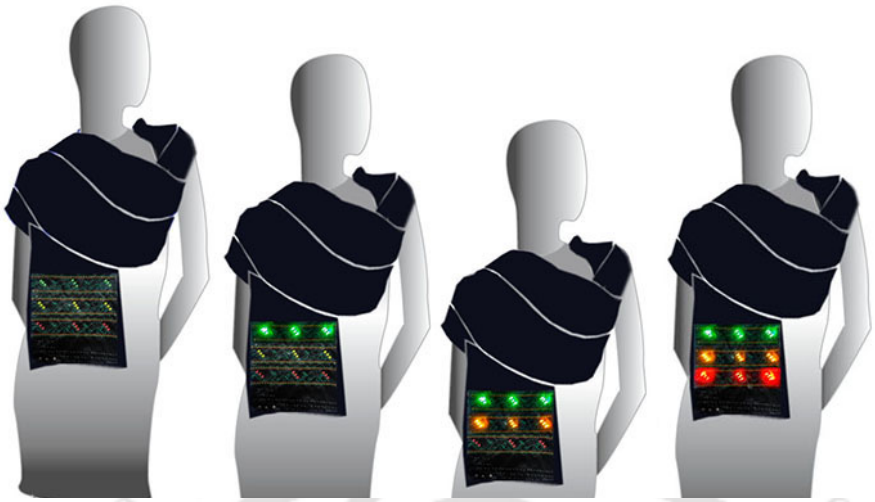
Annexure 12: Photographs of the prototypes



The three scarf prototypes



Prototype scarf 1 rendered on mannequin



Prototype scarf 2 rendered on mannequin

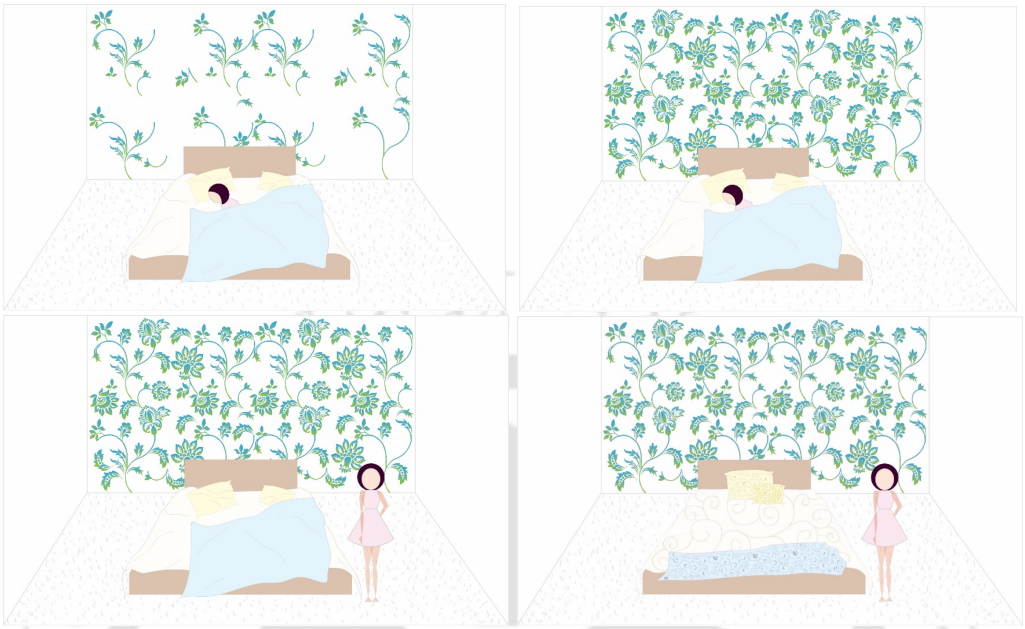
Prototype scarf 3 rendered on mannequin

Static jacket for Experimental Study 3

Model wearing Dynamic Led jacket for Experimental Study 3 – close ups

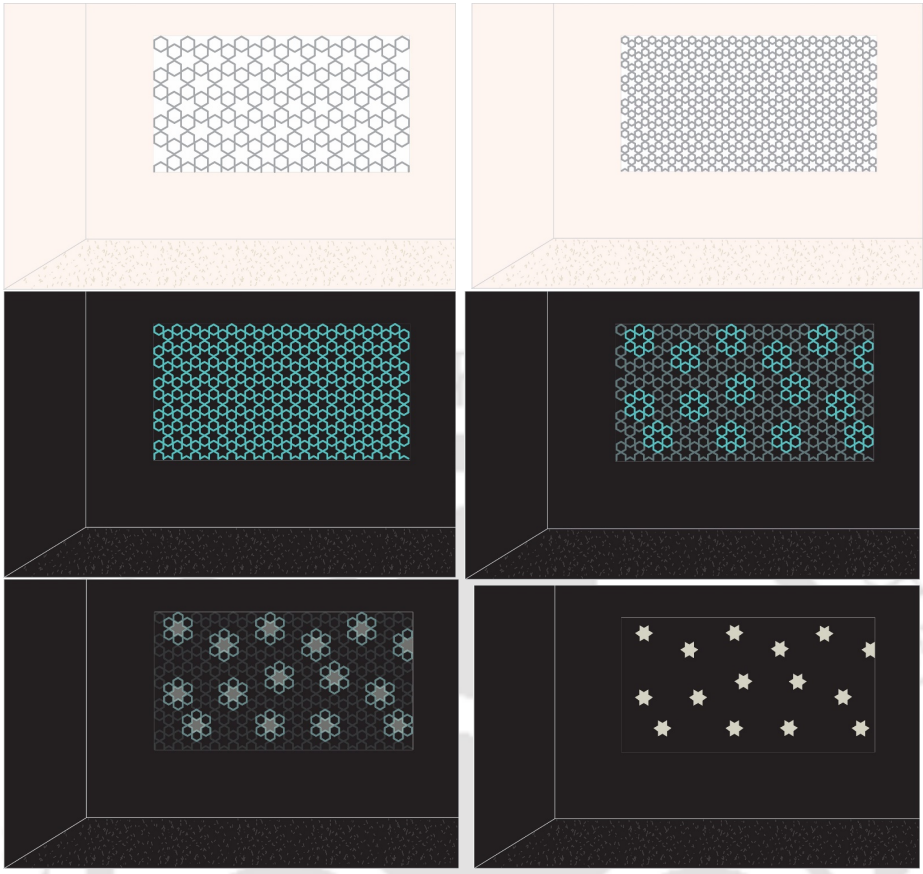
Model wearing Dynamic Led jacket for Experimental Study 3 at the cafeteria – group photos

Annexure 13: Concept story boards elaborated – Figures 4.15-4.20

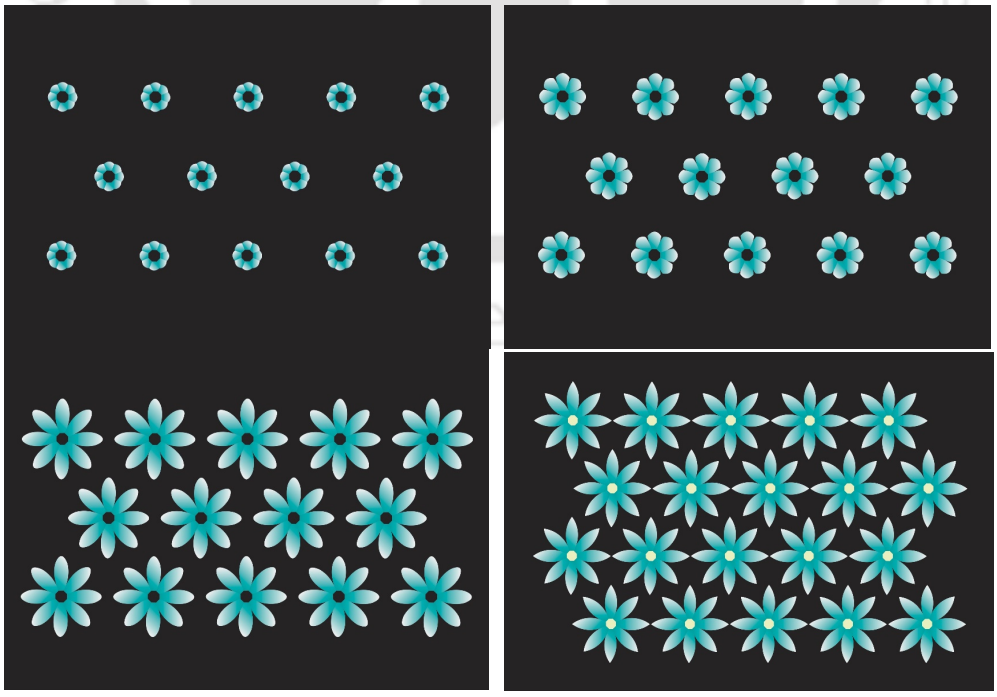


Storyboard 1 – User wakes up in the morning: Wallpaper completes as alarm tone rings; Bio-monitoring as user stands on the smart rug; Sheets auto adjust and patterns appear when set-up is complete.

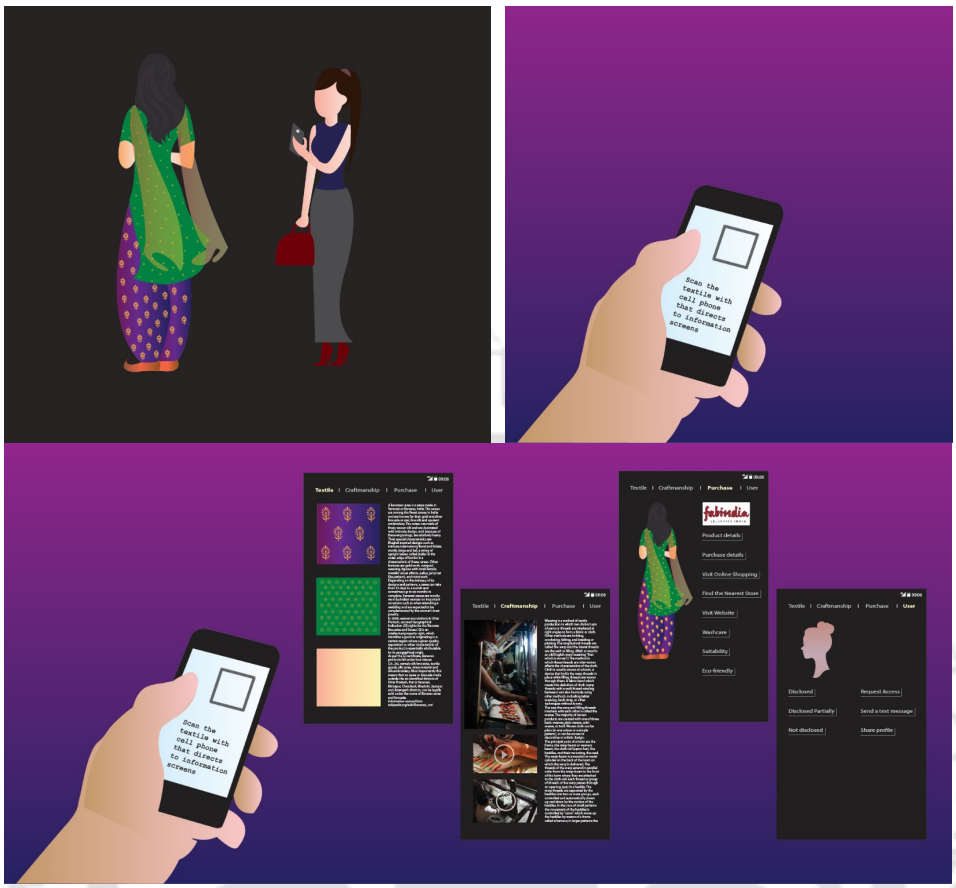
Storyboard 2 –Interactive wardrobe: Smart wardrobe with clothes that change shape, size, colors and patterns



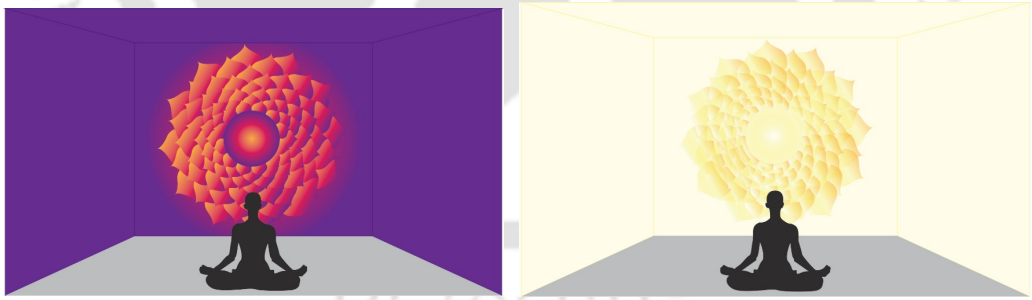
Storyboard 3- Screen that adjusts opacity and illumination



Storyboard 4 – Scarf with dynamic floral elements: Flower patterns opening and closing



Storyboard 5 – Traditional textile repository



Storyboard 6 – Textile wall displays for therapy and meditation

List of publications emerging from present doctoral research

Full papers

1. Deepshikha and Yammiyavar P. 2019. Role of digital crafts for nonverbal self-expression in the Indian social space. Design-Tech June 18-19, 2019. Technion, Israel Institute of Technology, Haifa, Israel.
2. Deepshikha and Yammiyavar P. 2019. Expressions of traditional textiles of India– A cultural probe. International Journal of Affective Engineering. Vol. 18, Iss. 2, Pp. 101-107. Japan Society of Kansei Engineering. Tokyo, Japan. DOI: https://doi.org/10.5057/ijae.IJAE-D-18-00016
3. Deepshikha & Yammiyavar P. 2018. Interactive Textiles: Significance and Social Acceptance. Human-Work Interaction Design (HWID'18) – Designing Engaging Automation 5th IFIP WG 13.6 Working Conference, August 20-21, 2018. Aalto University, Espoo, Finland.
4. Deepshikha & Yammiyavar P. 2018. Empowering textile crafts through the Internet of Things technology. Third International Conference ICT for Sustainable Development (ICT4SD), August 30-31, 2018, Goa, India.
5. Deepshikha, Yammiyavar P. 2018 A Comparative Study of Attitude Formation During Online and Real-Life Socialization and Its Implications on Design of Textile Wearables. In Proceedings of the 7th International Conference on Kansei Engineering and Emotion Research 2018. KEER 2018, Kuching, Malaysia. Advances in Intelligent Systems and Computing, vol 739, pp 85-93. Springer, Singapore.
6. Deepshikha, Yammiyavar P., Nath N. 2018. Textiles as communicating links for cultural traditions. In Proceedings of the 7th International Conference on Kansei Engineering and Emotion Research 2018. KEER 2018, Kuching, Malaysia. Advances in Intelligent Systems and Computing, vol 739, pp 168-177. Springer, Singapore.
7. Deepshikha, Yammiyavar P. & Nath N. 2017. Smart textile trends and their implications in digitizing craft traditions. In Proceedings of International Conference on Recent Trends and Sustainability in Crafts and Design- A treatise on recent trends and sustainability in crafts and design. IICD 2017, Jaipur, India. ISBN: 978-93-86724-21-2.

8. Deepshikha, Nath N. & Yammiyavar P. 2017. Moods Evoked by Traditional Indian Textiles - An Exploratory Study; International Conference on Creativity and Cognition in Art and Design, ICCCAD, NIMHANS. Bangalore: Bloomsbury India, 2017.
9. Pradeep Yammiyavar and Deepshikha. 2018. Exploring potential of traditionally crafted textiles to transform into e-wearables for use in socio-cultural space. IFIP Advances in Information and Communication Technology. Human-Work Interaction Design (HWID'18) – Designing Engaging Automation 5th IFIP WG 13.6 Working Conference, August 20-21, 2018 Aalto University, Espoo, Finland. Springer Nature Switzerland AG, Cham.

Posters and Demo:

1. Deepshikha & Yammiyavar P. Traditionally crafted digital interfaces. ACM SIGCHI International Conference on Interactive Surfaces and Spaces. November 25-28, 2018. Tokyo, Japan. (Poster – Extended Abstract)
2. Deepshikha & Yammiyavar P. Crafting textiles of the digital era. ACM SIGCHI International Conference on Interactive Surfaces and Spaces. November 25-28, 2018. Tokyo, Japan. (Demo – Extended Abstract)
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