INTERFACE COMPLEXITY
OF
PERSONAL DIGITAL ASSISTANT

An empirical study of linear and non-linear menu

By

SANJAY KUMAR TRIPATHI

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Abstract

Researches into usable interface of small screen portable devices are rare in academic field. The proposed study addresses the problems of interface complexity of ever becoming small devices. This thesis resulted from applied research using experiment based- empirical study on the use of small screen display interface of personal digital assistants. The whole study is carried out in the light of man- technology and organisation relationship. Small screen display interfaces are quite often used in specific organisational setting e.g. medical equipment used by medical practitioner in hospitals. In these specific settings, usability of these interfaces is a matter of great consideration. This thesis discusses interaction design patterns as a promising technique to incorporate explicit design knowledge into the design process. User interfaces are composed of many elements that are put into a specific structure. Patterns are a means to try to understand why some arrangements of elements are better compared to other and under which circumstances. This is exactly the kind of knowledge, which gives designers a better understanding of their tools of the trade so they will get better at using them. In order to make user interface design more of a human- engineering discipline, it needs to excel in analysing the problem well and creating solutions using valuable design knowledge. User interfaces in PDAs mostly consisting linearly arranged menu as they are directly translated from their desktop counterpart. On a typical desktop screen, the user has many different ways to interact, often with varied interaction styles (menus, direct manipulation, text, etc). The desktop environment is rich compare to the "impoverished" interfaces of handheld devices. While a range of menu placement and manipulation schemes have been proposed for large screen devices, these schemes are not appropriate to handheld devices. This study helps us in understanding linear and non-linear types of menu arrangements and their complexity of use in small screen devices. Additionally effect of menu depth in users performance is determined in case of most widely used linear type of menu structures. This dissertation examines use of non-linear menu in small screen devices and tests if they are proved usable when used for specific organisational tasks. This dissertation is furnished in way to provide empirical results on linearity and non-linearity of menu structure in small display devices.

Keywords: User Interface, Personal digital assistant, Linear and non-linear menu, Man-Technology- Organisation, MTO, Human-Computer- Interaction, Usability, Interaction design

Dedication

To

My Parents,

For all the love and care, you have given to me.

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After two degrees, in two countries, at three universities, in four different disciplines, I have learned one thing – I could never have done any of this, particularly the research and writing that went into this dissertation, without the support and encouragement of many people.

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Table of content

List of Figures

List of Tables

List of Names and Acronyms

3G	3rd Generations
API	Application Programming Interface
ABI	Application Binary Interface
BBC	British Broadcasting Corporation, London
CD	Compact Disc
CPU	Central Processing Unit
DOS	Disc Operating System
EISA	Extended Industry-Standard Architecture
ESDI	Enhanced Small Device Interface
GPS	Global Positioning System
GUI	Graphical User Interface
HCI	Human-Computer Interaction
IDE	Integrated Device Electronics
ISA	Integrated Systems Architecture
ISO	International Standard Organisation
IT&C	Information Technology and Communication
I/O	Input/Output
LU	Logical Unit
MTO	Man- Technology- Organisation
OS	Operating System
PC	Personal Computer
PDA	Personal Digital Assistant
PIN	Personal Identification Number
s	Seconds (time)
SCSI	Small Computer System Interface
SIM	Subscriber Identity Module
SMTP	Simple Mail Transfer Protocol
UI	User Interface
USB	Universal Serial Bus
WAP	Wireless Application Protocol
WiFi	Wireless Fidelity
WYSIWYG	What You See Is What You Get
WYSIWYN	What You See Is What You Need
WWW	World Wide Web

Key Definitions

3G, 3rd generation	3G is a global development of communication standards and technologies that enable the user to access multimedia services with a mobile terminal. It is characterised by the convergence of mobile phones and the Internet, high-speed wireless data access, intelligent networks, and pervasive computing
Communicator	A mobile terminal with PDA and data communication functionality.
Complexity	Complexity is difficult to define explicitly, for example, with mathematical clauses. In this study, the term is used to address a system that has large number of dependencies, relationships, unknown factors, changing elements and dynamic components, leading to a system difficult to develop, maintain, or change.
Ergonomics	The scientific foundation, both in terms of data and methodology, for a human-centred approach to design; knowledge and methods that aim to develop product, equipment, furniture and environment to fit the user's capabilities and to promote user safety and health.
Ethernet	A type of networking technology for local area networks; originally developed by Xerox Corporation; coaxial cable carries radio frequency signals between computers at a rate of 10 megabits per second.
Evaluation	Assessing the effect of something, judging or fixing the value or worth of something
Experiment	In an experiment, the investigator sets the users a series of tasks and quantifies their performance
Human-computer-interaction	Human-computer interaction (HCI) is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them (ACM 1992).
Hypertext	A term coined by Ted Nelson around 1965 for a collection of documents (or "nodes") containing cross-references or "links" which, with the aid of an interactive browser program, allow the reader to move easily from one document to another
Interaction designs	The selection of behaviour, function, and information and their presentation to users (Cooper 1999, 22).
Iterate	To repeat until a condition is met (repeat x until y)
Observation	Technique to gather data. Researchers observe (visually) the

phenomena of user-product interaction systematically, directly or based on recordings Participation User involvement in the design and evaluation of the product with a possibility to influence the decision.

Performance The measurable degree to which a user, product or system performs.

Prototype A demonstrator to be created to represent the product built for testing and experimentation

Simulation Initiating representation of equipment, events and task performance

Subject An individual interacting in an experiment, a user in a user trial, an individual involved in some way in a study

System A combination of multiple elements or components

Task The activities required (used or believed to be necessary) achieving a defined and desired goal; transform the initial state of an object to the final state

Usability The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (ISO 9241-11 1998)

Usability engineering Measurement of the usability of a product to find out the needed characteristics of the developed product, measurement, and development of usability characteristics vs. requirements

Usability study Systematic heuristic or experimental evaluation of the interaction between people and the products, equipment and environments they use; cf. user trial

User interface concept An idea of the logic, look and feel of a user interface.

User, **end-user**, human, citizen, consumer, individual, customer: individual human being interacting with a product or system

User-centred design Human-centred design

User-interface A combination of input and output parts, ways and procedures (technology) through which a user interacts with a product both cognitively and physically; the assessable aspects of the interface between a product and a human

Chapter 1

Overview and motivation

1.1 Introduction

In our daily life, humans are quite successful in conveying ideas, exchanging views and reacting appropriately to each other. What makes it possible is due to many fundamental aspects of life with which, we are living together and developed since evolution of human civilisation. These aspects or factors are the richness of language we share, the common understanding of how the world works, and an implicit understanding of everyday life. When humans talk with humans, they are able to use information from context or situation and can manipulate easily with greater degree of freedom to convey the information. Unfortunately, this ability to convey ideas does not work well when humans interact with a passive device like computers or PDAs. These appliances do not understand our language, do not understand how the world works, and can not sense the information about the current context at least not easy as most humans can. To understand this we should be able to understand the interaction aspects between these two. In fact, interface complexity is an underneath problem of interaction aspect. Focus of this chapter is to be introduced into the broad understanding of interaction and complexity in light of man-technology and organisation relationship. A general statement on research problem is prepared and discussed.

To achieve this, structurally, the chapter is organised in nine sub headings starting from basic human-computer-interaction concept to organisation of thesis.

Since complexity of interface is primarily understood as an interaction problem between humans and computers. At the very first, we will come across the subheading "Human-Computer- Interaction [1.3] to become aware of most common complexity problems in interaction", which gradually points towards mobile hci [1.4]. Man, technology and organisation under socio-technical aspects of human centeredness is elementary model of our research interest, and discussed in [1.6] as conceptual foundation. Finally, background and outline of thesis is presented [1.8 & 1.9].

1.2 Motivation

The future computing environment will be ubiquitous, invisible, embedded, tangible, virtual, active, integrated, interconnected, interoperable, and mobile. These characteristics define an environment that is always on, always at hand, pervasive, and blended. They reveal a vision in which the physical and virtual environments are tightly intermingled and much less distinguishable than they are today. In this apparition, people are supposed to communicate with an array of information-based devices using a variety of modalities. In this vision communication, media, information resources, commerce, and entertainment seem to be converged together. In this environment, people's bodies may be blended with devices that are worn or implanted, and they travel through hybrid physical- virtual spaces populated with active and aware artefacts that behave in symphonic harmony to produce a nearly seamless biophysical-psychosocial-cyber-kinetic reality.

Therefore, research into usable, useful and effective approaches for users to utilize the full span of mobile devices is vital. Unless effective user-cantered approaches are developed and applied, the promise of wide access to the information resources will be lost, with users left frustrated and overwhelmed (Shneiderman et al., 1998). In addition, there is a need to research on the psychological impact of small screen devices such as PDA. This proposed research study, reviews, investigates, testifies, and discusses experiments on the usability impacts of embedded software and structural aspects of user interface specifically menu structure on small screens for supporting device applications.

On a typical desktop screen, the user has many different ways to interact, often with varied interaction styles (menus, direct manipulation, text, etc). The desktop environment is rich in comparison to the "impoverished" interfaces of handheld devices. While a range of interesting search result visualization and manipulation schemes have been proposed for large screen devices, these schemes are not appropriate to handheld devices. Marsden & Jones (2001) emphasised that

> *"An interface must therefore better support comparisons and provide an easier way to discover a handset's functionality"*

As computation becomes ubiquitous, and our environment is enriched with new possibilities for communication and interaction, the field of human-mobile device interaction confronts difficult challenges of supporting complex tasks, mediating networked interactions and exploiting the ever- increasing availability of digital information. Research to meet these challenges requires a theoretical foundation that is not only capable of addressing the complex issues involved in effective design of new communication and interaction technologies but also one that ensures a human-centred focus.

Although PDA manufacturers have attempted to improve handset menus, their attempts have been in principal superficial. If we are to empower the users of ubiquitous computing, then some new form of interaction must be developed.

Menus were originally designed to exploit the truth that humans are better at recognising commands from a list rather than recalling a particular command name from memory.

When initially introduced, menus provided an easy-to-use alternative to the more prevalent command line systems. Certainly, given the limited keyboard size in case of cellular handsets, menus represent a significant advantage over any command line system. The constraints in screen size and form factor also favour menu-based dialog over a mouse based graphical user interface. Consequently, the reasons for choosing a menu-based interaction would seem sound. Therefore, all available handsets currently support some form of hierarchical menu to access the functionality of the device. None is well, however. Techniques, like menus, translated directly from desktop to hand-held, without fully considering the consequences, can cause interaction problems. The reduced size of embedded computer systems means that interacting with handset menus is more burdensome than their desktop counterparts – Han & Kwahk (1994) reported in a study that

"Users being up to three times slower when using menus on a small screen"

In case of PDAs, this can cause frustration and complaint from many users. Most vocal among these are cellular service providers who are losing revenue. Furthermore, they find it impossible to market vertical services, as potential customers cannot configure their handsets to use these premium services.

The common way to access various functions in a PDA is to use a menu feature. The menu is arranged hierarchically so that the number of available items in a single selection list can be kept within reasonable limits. Besides, it guides the user logically through various features in the device.

Now in the era of rapidly changing communication technology, it is expected to use PDA's also for their screen-based features like Rich content (data, audio, and video) in most advance case also for decentralized computing. Reduction in screen size from full screen to PDA-display size results into drop of user's performance in application delivery. Han & Kwahk (1994) reported that

> *"The smaller the screen, the less information is displayed at one time, making the user interface central in application delivery".*

The main reason for this is that on a smaller screen, it becomes increasingly more difficult for a user to make good quality judgments about the usefulness of particular menu. Also, poor search result choices can be disastrous in human-mobile device interaction terms: as one study revealed, some of users became completely lost, spending 10 minutes trying to find information on a PDA screen that took 10 seconds to locate on a conventional desktop computer. In a WAP field study, Nielsen (2000) reported that

> *"Early feedback from those using cell phones for checking weather, reading news headlines, and getting sports scores indicates that they will not tolerate endless scrolling or key presses just to retrieve data[1]".*

In the mean time, handheld devices came into existence as the result of convergence of communication and computation devices. Voice centric development trend in communication devices resulted into pager and computation-centric development trend in computational devices converged into handheld PCs and PDAs. As both are based on different technological streams, market players tried to establish their own brand. Microsoft Windows CE operating system brought their user interface to small devices though they were primarily designed for conventional desktop. Much work has been done to reduce the complexity of user interfaces in desktop, but there is no evident work for the small computing devices such as PDAs. In this study we will investigate users performance and interface complexity i.e. system complexity rather than to test for behavioural and cognitive complexity [see Rauterberg & Aeppli, 1995]. Increased demands of small interface devices but continuous ignorance of academic research to reduce the complexity of these devices for different group are the principle reason that motivated me predominantly for this research. As discussed later in the chapter this study goes through technical advancement side-by-side stepped into the topic explaining the involved academic streams.

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[1] Retrieved from www.useit.com/alertbox/20001210.html on 23.09.2003

1.3 Human Computer Interaction (HCI)

One might ask! Why I am interested to look upon human computer interaction theory? It is rather a matter of thinking as the work is concerned about a mobile device specifically personal digital assistant. Personal digital assistants and many other handset or cellular devices are actually resulted from the convergence of traditional desktop (most common computing machine) and mobile/cellular phones. Initially there were no separate guiding principal for these small devices. As more and more technological advances came, these devices have taken scientific principles applied to those for desktop computing devices. Hence, Let us examine critically the theory and practices in HCI that could have influence in mobile handset interfaces. In the coming paragraphs, I will explain about HCI and criticism from different approaches.

Unanimously accepted, Human- computer interaction is an interdisciplinary area of applied research. Its fundamental concern is to understand and facilitate the foundation of "user interfaces" existing in computers and manipulated by human users. In doing so, experts realised and accepted many established area of science and art: psychology, computer science, anthropology, management science & industrial design etc. Among them applied psychology is still enjoying the principal concern of many researchers, as stated by Carroll (1991)

> *"Psychology of HCI addresses itself to understanding how human motivation, action, and experience place constraints on the usability of computing equipment and to support the development of new computing technology that exploit these constraints".*

In contrast, present work is though a sub domain of HCI, better called as mobile HCI; I am inducing here the relevance of work and organisation psychology as the guiding scientific stream. In coming sub chapters, I have explained in details while discussing about the basis model of my research study i.e. man- technology-organisation. Let it here only be concerned about the extent and contribution of classical HCI approach to understand it better as an influence in the repeating research practices in human computing devices or in small handsets.

According to Carroll (1991), HCI seeks to produce user interfaces that facilitate and enrich human motivation, action, and experience, but to do deliberately it must also incorporate means of understanding user interfaces in terms of human motivation, action, and experience. This is the conceptual region of psychology. Conversely, the design and use of computing equipment provides psychology with a diverse and challenging empirical field to assess its theories and methodologies.

What create the field of Human- computer- interaction? Our concern come out from the problem of where the boundaries of the field are, or should be, and why it might be of importance (Bannon, 1985). The HCI brand appears to be self-explanatory – that is anything to do with people interaction with computers- yet it has been interpreted more narrowly as simply the study of user interfaces. Carroll & Campbell (1989) examine a number of states as to what HCI is, and end up with the claim:

> *"HCI exists to provide an understanding of usability and how to design usable computer artefacts."*

From the point of view of software practitioner or designer, HCI is often viewed as the area of "human factor" in the workplace today. While coming across at the work that comes under the field of HCI, we can see a number of different premises, not always expressed. The HCI area can be seen as an applied domain for the testing of general cognitive theories. The focus is on the theory or model, rather than on building better interfaces per se. Other researchers, especially those in commercial settings, are more driven by applied concerns. They wish to make a difference in design of interfaces, whether there is a clear theory behind the changes. The idea that solid theory spills down into applied practice, a not exceptional conviction, has been shown to be quite untrue for many domains as shown by Carroll & Campbell (1989). To date, the HCI research contribution has been more to criticise current design practices for not paying enough attention to users (e.g. Gould & Lewis, 1985), or to offer rather general and often not very usable guidelines (Rubinstein & Hersh, 1984 ; Shneiderman, 1987), or to speculate on alternative ways of doing things in HCI without much practical foundation (Norman & Draper, 1986).

There is currently no common agreed definition of the range of topics, which form the area of human-computer interaction. However, we need a characterisation of the field, Therefore, I am offering a working definition that at least permits us to penetrate into the practical work:

> *"Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them"*

From a computer science standpoint, the centre of attention is on interaction and specifically on interaction between one or more humans and one or more computational machines. The classical state of affairs that comes to mind is a person using an interactive graphics program on a workstation. However, it is clear that varying what is meant by interaction, human, and machine leads to a rich space of possible topics. Interaction with mobile devices would wish to identify as more central.

Taking the notion of machine instead of workstations, computers may be in the form of embedded computational machines, such as parts of spacecraft cockpits or microwave ovens. Because the techniques for designing these interfaces bear so much relationship to the techniques for designing desktop interfaces, they can be profitably treated together. But if we weaken the computational and interaction aspects more and treat the design of machines that are mechanical and passive, e.g. design of a hammer, we are clearly on the margins, and therefore the relationships between humans and hammers would not be considered as a part of human-computer interaction. Such relationships clearly would be part of general human factors, which studies the human aspects of all designed devices, but not the mechanisms of these devices. Human-computer interaction, by contrast, studies both the mechanism side and the human side, but of a narrower class of devices. On the other hand, consider what is meant by the term “human”?, If we allow the human to be a group of people or an organization, we may consider interfaces for distributed systems, computer-aided communications between humans, or the nature of the work being cooperatively performed by means of the system. These are all generally regarded as important topics central within the sphere of human-computer interaction studies. If we go further down this path to consider job design from the point of view of the nature of the work and the nature of human satisfaction, then computers will only occasionally occur (when they are useful for these ends or when they interfere with these ends) and human-computer interaction is only one supporting area among others. To give a further rough characterization of human-computer interaction as a field, I am listing some of its special concerns:

- Human-computer interaction is concerned with the joint performance of tasks by humans and machines
- The *structure of communication* between human and machine; *human capabilities to use machines* (including the learning ability of interfaces)

- Algorithms and programming of the interface itself
- Engineering concerns that arise in designing and building interfaces
- The process of specification, design, and implementation of interfaces

Human-computer interaction thus has science, engineering, and design aspects while concerned about the computing devices. The same principle and theory is applicable with some deviations for the ever small becoming portable devices which are embedded in nature, mobile and doing up to some extent computing task in either form. Though it is not a classically accepted approach while researching small devices, it is the technological thrust and popularity among the users to consider it for further discussion. Therefore, among above listed concerns, the first two concerns of human computer interaction are of our interest (i.e. joint performance of tasks by humans and machines, the structure of communication between human and machine and human capabilities to use machines). Taking the discussion into a narrower spectrum, I am discussing the Human computer interaction with mobile devices in coming paragraphs.

1.4 Mobile HCI: Status and problems associated with interfaces

The study of human computer interaction for mobile devices is a relatively young research field in which commercially successful devices have only been available for less than a decade and leading conferences have only a few years of history (Kjeldskov & Graham, 2004). The term mobile HCI coined by a group of researchers in 1998 while thinking of organising a workshop, that would have been only dedicated to the small handheld devices. There may be strong disagreement – why it should not call as human- mobile device- interaction? It is rather known as human computer interaction with mobile devices (Mobile HCI). Mobile devices are coming in a wide range of variety according to their capability and functionality. Classifications of handheld devices are discussed in chapter 2 in detail. Human computer interaction term is simply associated with mobile devices as the mobile devices are incorporating day-by-day computing capability within the system itself. We are investigating user interface complexity of personal digital assistants in this study, user interfaces are primarily considered as the display content of the available screen. As researcher started to work with the human components, which are directly responsible for interactivity between man and machine, it became essential to consider the software logic running behind the system too.

If we consider the case of current wireless technology use, we find that many environments including offices, automobile, classrooms, meeting rooms, conference halls are already containing computers and computerised appliances. Research laboratories are engaged in developing smart homes of the future that will be supposed to have ubiquitous embedded computation facilities. Mobile HCI concerned of subject matter, as the user enters one of this environments carrying a mobile device, how will the device interact with the immediate environment. Mobile HCI is confronting many interesting research questions, such as how to provide a user interface that extent over multiple devices that are in use at the same time. How can the user's mobile device be effectively used as personal universal controller to provide an easy-to-use and familiar interface to all of the complex appliances available to the use? How will user and system decide which functions should be presented and in what manner on what device? How can communicating mobile devices enhance the effectiveness of meetings, classroom lectures or even small industrial distributed applications?

Kjeldskov & Graham (2004) reviewed research methods applied within the field of mobile human-computer interaction. The purpose was to provide a picture of current practice for studying mobile HCI to identify shortcomings in the way research is conducted and to propose opportunities for future approaches. About 102 numbers of publications on mobile human-computer interaction research were categorized in a matrix relating their research methods and purpose. The matrix revealed a number of significant trends with a clear bias towards building systems and evaluating them only in laboratory settings, if at all. In addition, gaps in the distribution of research approaches and purposes were identified; action research, case studies, field studies and basic research being applied very infrequently. Consequently, Kjeldskov & Graham (2004) argued that the bias towards building systems and a lack of research for understanding design and use limits the development of cumulative knowledge on mobile human computer interaction. This in turn inhibits future development of the research field as a whole.

Mobile HCI has to do mainly with the usability of application, either as service interface or just about the user interfaces, control of the device, visual representation, ergonomics, context awareness, interaction and navigational issues etc. much research are intended towards the market strengthening of application provided by the device manufacturer. Much resources are mobilised towards the internet based applications and m-commerce.

User interface of the small handheld is an important and rather unavoidable area of research. To date Internet service user interface e.g. location based information's or city route navigation has attracted more the researcher, less emphasis has given to the basic user interfaces (e.g. menus) and interaction style with different small display devices (e.g. PDAs). To the next, I am listing some of the researches done in previous years.

Myers (2001) used PDAs as in a second-level chemistry class with about 100 undergraduates to enable the instructor to ask multiple-choice questions and get bar graph of all students' answers. These helps keep the students thinking about the material and allow the instructor to evaluate the student's level of understanding during the lecture. The students reported a strong preference for using the mobile devices over non- computerised alternatives, such as raising their hand or using the paper.

Colbert (2000) conducted a diary study of rendezvousing considering group size, time pressure, and connectivity in mobile devices. The study found that approximately 5-10 % of rendezvous caused a notable amount of stress and/ or lost opportunity (rated at 4 or 5 out of 5.5 = high).

Gonzalez-Castańo et al. (2001) presented a new transcoding technique for www navigation on small display devices named "Hierarchical Atomic Navigation". Unlike previous techniques, this kept all original information in a readable way, without imposing the use of a specific browser. To achieve this goal they used a navigator interface to represent original content in symbolic form. A set of representative icons replaced unreadable elements. This technique was extreme useful to any PDA, regardless of operating system and browser choice.

Leiner & Honald (2003) discussed the challenges before designing the user interface for mobile phones. They have taken practical examples of mobile phone user interfaces and discussed the design alternatives. They have concluded that the aim of usability experts is to represent users and simultaneously to support product manager and marketing team to realise their visions. Intention should not be to make compromise between industrial design, marketing and software development but to find a common optimum usable experience.

Degen (2003) worked out the usability engineering process at Vodafone global communication specifically on MMS- Album. In particular, they have discussed the problems of different channels and mobile device type.

A research in interaction problem, complexity and for alternative user interface is almost absent. While literature review, we found few quite relevant work done on mobile HCI, in coming paragraph we will examine the findings of one of this research to build framework of our research.

To develop new user interaction principle for mobile and ubiquitous HCI, Holland et al. (2001) identified various major problems with mobile HCI. They have concluded that:

> "*User interface for mobile devices are typically dealing with four general problems: Firstly, only limited screen real estates available; more generally, taking into account non-visual forms of feedback such as auditory display, feedback bandwidth is limited. Secondly, the bandwidth, precision and convenience of input devices are generally restricted. A third problem is that many mobile devices are typically used in* ***minimal attention situation****, where the user has only limited, intermittent attention available for the interface. In such situations, interactions with the real world are generally more important than interactions with the computer, the users hands and eye may be busy elsewhere, and the user may be busy avoiding normal hazards of moving around, as well as engaging with real world tasks. Fourthly as devices diversify and proliferate, users increasingly face the need to make two or more devices* ***interoperate for some ad-hoc purpose****. Even where each device has a well designed user interface, this kind of task can be hard to arrange*."

The above mentioned four typical problem where minimum bandwidth, input mechanism, minimal attention situation and interoperability, these four factors alone or in combination can cause difficulties if the user does not know, can not recall or can not locate the commands needed to make the device carry out a desired action. Let us extend the discussion subject to the condition "if the user does not know, can not recall or can not locate the commands". Considering it is not a primitive case: the user is supposed to have some basic knowledge about the device, he has at least short duration memory capacity, and an understandable user interface could help him to choose desired command. What may be the cause of complexity to use? It may be either ability to learn or ease in understanding interface. Whether menu or any other type of interface, learning ability may improve the skills of user from novice to expert, but only when user finds himself in a state to understand the mechanism of using interface in an understandable shape. Therefore, an alternative user interface (e.g. Linearity and non-linearity of menu structure) becomes crucial. Holland, David

& Henrik (2001) further emphasised that:

> *"For mobile devices and their typical context of use, it is often inconvenient, impractical or too time – consuming to navigate to the appropriate screen or to otherwise search the space of available commands to effect the appropriate action"*

Space of available commands could be the common interface consisting of graphics, icons or labelled buttons in most simple case of application, or space of commands may be structured set of actions by which user is retrieving information from some specific application such as spread sheet in a PDA display. Such an application needs many steps to perform the task and it is only possible through the selection menu, where user is bound to proceed in a systematic way and finally to complete the task successfully. Study on efficiency of linear and non-linear menu would be proving meaningful if it suggest, "That at any point of using mobile device user knows exactly what to do next, and he is able to recall the action easily and can locate the command conveniently".

User interaction problem identified within the menu selection can be viewed in part as problems of search. That means it causes problem whenever a mobile device does not immediately offer the currently desired action, and therefore, users are forced to navigate the interface, drill down, scroll or otherwise search the interface for the item needed to perform the intended action.

Since last few years some researches are being conducted related to small handheld devices, spectrum and field is still not fully explored in case of mobile devices. However, university level research is taking pace to investigate more on the issue of interaction styles with mobile devices.

There is no evident work either documented or published to mark the history of development regarding the interaction style of small mobile devices. We wish to use as a partial benchmark to understand the interface research and development cycle just by comparing the classical human-computer- interaction style development over the period.

Myers (1998) identified six major areas i.e. gesture recognition, hypertext, text editing, windows, mouse and direct manipulation of graphical object. It has been universally observed and I have already stated earlier in this chapter that interaction metaphor as a whole is symmetrically transported to the handheld devices as it started to converge between two streams of voice and computation. Gesture recognition is being realised through virtual reality and augmented reality where scientists are trying to combine the "always active" and "everywhere present" states of interaction. Introduction of WAP[2] and mobile browser are doing nothing but presenting tiny version of Hypertext language. Until now, short messages are the most popular application among the user showing text editing as simple and robust activity. Introduction of Windows CE[3] takes window metaphor to small portable consumer electronics whether PDAs or portable PC. Mouse analogous external user interfaces are available in wide range to assist the operation of PDAs etc. Example of non-linear menu, as a graphical object is the new innovative idea of menu representation that can be handled as direct manipulation of graphical object.

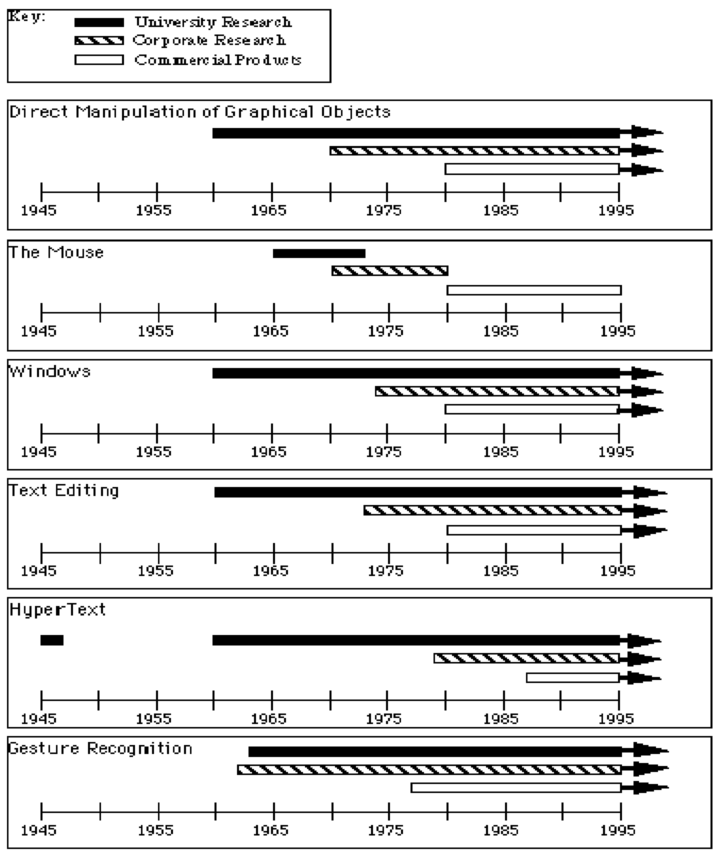

Figure 1-1 Timeline showing major interaction style

Figure 1.1 is showing general research area at three level of institution i.e. university, corporate and commercial product. Myers (1998) summarised the

[2] WAP: Wireless Application Protocol, a standard to write web application for mobile devices
[3] Small version of operating system for handheld devices by Microsoft corporation enabling user to operate various range of small handheld in the same fashion as desktop.

historical development of major advances in human-computer interaction technology, emphasizing the pivotal role of university research in the advancement of the field.

From the figure 1.1, it is quite evident that, research in interaction style was confined only to gesture recognition, hypertext, text editing, windows, mouse, and direct manipulation techniques, until 1995. Even academic research on menu technique was not done to explore other ways of interacting with application. Whether it is a simple desktop application or PDA, menu plays a pivotal role to work with application. Human beings are of varying working capacity (e.g., some are excellent in mathematics and some are well in philosophy) similarly, to work with a particular kind of menu structure can be different for different group of people. It may be due to various factors viz. habits (by birth or due to work), general intelligence, learning ability, and repeated use etc. In the same way, a particular kind of menu can be well suited for a specific organisational need. Working in a monotonous environment in an organisation (e.g. working in an assembly line) can change working habit of a person. It cannot be over ruled that for some task in an organisation humans may better perform with alternative techniques. Therefore, it can also be supposed that, for a specific task, the same menu pattern, which we inherited from windows based application, cannot be suitable. It is therefore, technology, user and organisation together constituting a meaningful basis for researching these interdependent entities. Based on the above theory of inter-relationship between users, technology and organisation, it is not wrong to build a model to investigate these to find if alternative structure of menu may also be effective in case of PDAs.

1.5 Research model: MTO as conceptual foundation

The guiding model of current research is Man-Technology- Organisation, which is actually evolved from modern German work and organisation psychology theory known as “Mench-Technik-Organisation” (MTO). According to MTO, it has been seen as in any working productive environment i.e. Organisation, human being and technology are the basic part of the whole framework. They are closely inter-related with each other and responsible for enabling frictionless functioning.

Every organisation has pre-defined task to perform by their employee (Human). To achieve the optimum level of productivity, these tasks are generally performed with the help of certain tools or apparatus (technology) – it may be any kind of robust machinery or high-tech computing device depending upon the necessity and requirement.

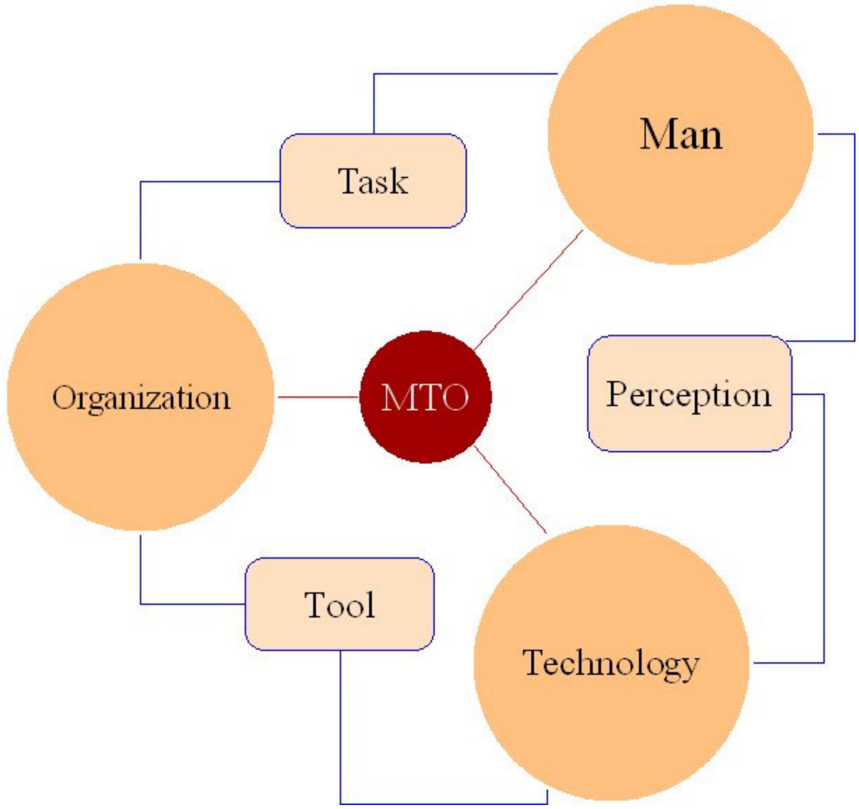

Figure 1-2 MTO Relationships

Let us discuss here typical scenario of modern industrial structure. The implementation of modern technologies led in the last years to important restructuring in the industrial production. Many enterprises strive to hold with the development of the modern technologies developments. This means that new concepts brought important changes to the introduction of modern technologies in the Organization itself. An extreme division of labour strengthened against operational sequences, which lead to a better motivation and a higher work satisfaction of the co-workers. However this depends on the fact that the modern technology not as specific obligation, but when task of organization is understood regarding appropriate organization and work structures. Extreme formulated goes it thereby around the decision in words of Ulich E.(1993)

> *"Whether humans are used as extended arm of the machine with a remainder function in an automation gap, or the machine as extended arm of humans with tool function for the support of the human abilities and authority"*

From these views it follows that modern technologies can be realized in the context of different concepts by work and organization structures. The introduction of such concepts is not worth neutral. Ethical reflections and evaluations can help here. In this connection, also, the important question arises, to what extent ethically justifiable concepts are economical.

In the past research one important question was neglected, i.e. to what extent the technical output of communication helps reticence and hurdle, which are present in the case of direct communication (Emery & Thorsrud, 1976), who determined this for telephone communication. Also It was faded out largely to ask what extent it concerns with the confrontation of human and technology typical communication concepts.

The concept presented here does not refer predominantly to the changed quality of human data processing for the regulation of socio-technical consequences of the computer technology and further its effect to cognitive structures of human communication and the man-machine-organization. It deals with the possibility of introducing such technology in an organisation for the humans working their in particular kind of task, in a way that all the three essential elements (Human, technology, and organisation) might be profited largely. Here, it should not be forgotten that human beings have certain perception, technology limits itself by its capacity and organisation has predefined goal to achieve making use of technology and their employee.

With the rapid change in industrial processes, everyday new and modern hi-fidelity systems are being employed. Their objectives are not only to increase productivity and competence at global level but also to provide comfortable working environment for working humans. Therefore, Exploring interface complexity of a PDA with a view to investigate alternative menu structure is useful in the context of man technology and organisation, as they are gaining increased popularity of being small and handy enough. Using PDAs in hospitals to maintain patient's daily record and in-field data collection using PDA for big research projects are few of examples.

Concept of MTO, thus, employed here make sense, if we can conclude whether an alternative structure of menu, has an effect to the performance of user and have effect on the productivity of an organisation (e.g. time saved by users to complete the tasks). Moreover, mobile phones alike small screen devices are well placed in daily uses and getting more popularity among the every section of our society. Hence, user friendliness (convenience of operation) of these interfaces is rather important to study. While using a technology in our daily routine life or at work place, it should be avoided that social components are pushed backward; otherwise, it has always danger of losing the human acceptance of such technology. In the coming paragraphs, we are taking social components of a technology in consideration and examine to fit into MTO model.

1.6 MTO: socio-technical consideration

Within the technology-oriented research in which various difficulties of communication and collection of homogeneous problem between technology and social oriented research groups have been reported repeatedly. It concerns to measure the efficiency of sociological explanation models for the man-machine interaction. The research proposed in the current works arises from the hypothesis that problem existing between the technology – and social sciences is compellingly necessary to investigate under the special consideration of socio-technical point of view. That means humans have considerable perception abilities, technology as such have definite functional capability and organization as a decision maker forming together an interdependent system of the man-machine function division. Here it does not go around out-passing against each other's but that result, which appeared relevant and interesting to the society, fit to regulate the man-machine interaction.

Derived of it and introduced by Zurich's socio-technical viewpoint [e.g. Ulich E., 1993]. As a result, it seems to achieve the aim of designing technology in such a way to consider human interest and qualification but also suitable for efficient work-organizational applications. This core thought confiscated from Ulich (1978:1990) who conceives principle on that a complementary organization by computer-assisted work systems is intended: taking under the consideration human weakness and strength as well as advantage and disadvantage of mechanical work process must always be aimed for effective man-machine interaction. As Weber *et al.*(1994) emphasised

> *"They will not only supplement but act as complimentary to each other to meet the challenges of difference between man and machine capacity"*

That means it is almost unavoidable to overrule socio-technical consideration while evolving new technologies in future and for their wide ranged acceptance. Therefore, in the following paragraph we are discussing innovation and challenges to be faced in socially compatible technologies and necessity for university level research.

1.6.1 Socially compatible technology

Socially bearable technique presents itself a particular foundation. It is not the technology, which propels economy and society, but it is the technology itself developing in society and economy independently. Social conditions would produce technology in accordance to need and necessity of the society. Technology and society are not to be confronted to treat separately but the development of the technology is to be understood as society-historical development. Here one must also acknowledge course of the mechanization, into which economic interests and cultural value work together and thereby are to be changed with the time. Böhret & Franz (1982) and Bullinger(1985) emphasised that

> *"The socially compatible technology can redeem its action and organization orientation only if on the basis of detectable effect by (employee i.e. technology user, work council i.e. technology facilitator) the action concerned as technology-steering and/or effect-compensating suggestions are sketched. Besides it is not meaningful to make technology valuation isolated but compared with alternative applications of technologies available"*

Only by such a projection, it becomes meaningfully realisable for the decision makers and organization as to have deep concern for social compatibility of a technology.

The concept of the innovations - and technology analysis enquire up, intersection area of social, technological and economic challenges. The public interest wishes itself more towards information about the possibility of individual use, but in addition, social consequences of future technologies. Innovation and technology research is an element of modern research, education and innovations policy. Science and technology are not meant to serve for self. The contribution, which new technologies can make for corporate problem's solution is controversial. Therefore, they can be used for a sustainable development where, technology and industry-oriented- innovation process integrated with university research is necessary. Here, university level research should develop and identify potential application of new technologies, searching risks and solutions to use these new technologies and further to formulate recommendations for policy making.

Thinking about scale of advancement, here I am citing words of Ernst Bloch- the great German philosopher- *"Thinking means going beyond" Yes: Thinking- research, knowledge, invention- that means exceeding the limit. However, we also know: every time we cross the limits puts us repeatedly before something new; before limits of new knowledge, before limits of human being that what we can, before the limits for what we can take responsibility. For that, we need to fix scale to help us while differentiating, what we may do and what may not*[4] [….]. While redeeming my proposed research work I had to think frequently about technological innovations, advancement and socially justifiable technological use. In a global advancing world, technological development is not to stop but to see for future orientation. Of course, technological innovation process will have more impact on society and policy making in future. *What may do and what may not.* will always be relevant which means research on socially justified technology use will be inevitable. Innovative technologies can only be acceptable if they meet the requirement of society and demand coming from society and economy of the nation. Without agreement of broad population circles, new technologies will not be able themselves to intersperse, although also here divergent social groups can show an agreement and/or a refusal conduct deviating from each other. Because the choice and use of new technologies are often affected by the social values and cultural norms of individual social groups, the policy and many other factors e.g. the open-mindedness in relation to ecological questions etc.

Man, technology and organization itself cannot be optimised always and have not to be seen as such, but in their interdependence and their optimal cooperating function style are rather to be valued. The MTO concept proceeds from the priority of the task. The task linked on the one hand to the social and technical subsystem, it connects on the other hand humans with the organization. Rather the task distribution between humans and technology, thus, plays the man-machine function division the crucial role for the development and construction of production systems. Consequently, their interpretation determines the degree of automation. Let us

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[4] [Original] "Denken heißt überschritten- das war das Motto von Ernst Bloch, dem großen deutschen Philosophen der Hoffnung, Ja: denken- forschen, wissen, entdecken- das heißt überschritten. Wir wissen aber auch: jedes Überschreiten von Grenzen stellt uns immer wieder vor neue; vor grenzen der Erkenntnis, vor grenzen dessen, was wir Menschen können, vor Grenzen dessen, was wir verantworten können. Dafür brauchen wir Maßstäbe, die uns unterscheiden helfen, was wir tun dürfen and was wir nicht tun durfen.[…]

examine their implication in coming paragraphs.

1.6.2 Socio-technical implications

The tradition of the socio-technical system organization begins in the fifties at the Tavistock institute in London (studies in English coal mines and in the Indian textile industry) and is transferred by Thorsrud in the sixties in the projects to „the democracy" to Norway (Emery & Thorsrud, 1976) and finally by Mumford (1987) referred to the development of computer systems. Mumford (2000) characterizes the socio-technical view point for the Participatory Design as "Socio technical Design is an approach that aims to give equal weight on to social and technical issues when new work system are being designed."

The socio-technical system is linked closely with the early development of the participatory system development and does not only understand this as substantial condition for success, but understands it beyond that in the sense of a value conception as fundamental principle. The beginning of the socio-technical system organization was also taken critical, since it explains insufficiently, how such systems develop and change dynamically. Consultation of theoretical insights to social systems (Luhmann, 1987) and a deeper analysis offer remedy in relation to these deficits of the interchanges between contingent, self-referential communication structures and more strongly controllable technical operational sequence. Under the aspects of this background the question arises, how the methods of the participatory analysis and organization of socio-technical systems can be supplemented, in order to the insights to the situational and limits anticipatory development of such systems (Suchman, 1995; Orlikowski, 1996).

In recent years, more and more discussions are taking place about the moment that human beings surpassed and substituted[5] by the machine. On the one hand, we are designing machines that embed more and more human intelligence, but at the same time, we are in danger of becoming more and like machines. These circumstances enforce us to consider three very basic questions: *What can we do (Man/ Human), what should we do (Task), what are the means or alternatives of*

[5] we wish to use word substitution instead of replacement – many researchers believes that machines are replacing human and his intelligence, although it is still not proved under different socio- psychological aspect up to which extent machines are replacing complex solution capability in comparison to human work force. Substitution would be the best fit as, machines are just taking a part of task directly or indirectly governed or controlled by human mental capacity behind them.

doing it (Technology /Tool or any other means of operations)

Within the basic framework of MTO, one can see how the discussion extends itself towards the “Task” in its centre. Of course, task in primitive case always is the centre of activity within an organisation. One could rate it according to its important hierarchies but “to do something” or “to achieve something” is the central idea behind productivity and in turns primary objective of every organisation. What we can do? As physically appeared object, it indicates only our capability or perhaps intelligence based cognitive capacity of us to perform some task. If we can perform some task – what should we do? Whether to perform some task is just to say or task itself has its own objectivity or importance. Then relational concept of human being, technology and organisation contributes here primary importance of task i.e. meaningful task to be performed. In what sense could it be meaningful? Moreover, why should it be designated as in terms of meaningfulness? One must accept task itself in its own periphery of presidencies as it being in central attraction of activity among human, technology and organisation framework. Meaningfulness or meaninglessness could be a matter of discussion. What ‘job’ or what kind of ‘target oriented task’ is only the useful entity for researcher to produce the qualitative empirical results.

What are the alternatives to perform these tasks –which are ever complicated and dependent of many variables- are always capable human or his aided companion to perform the task? German philosophy of “Humanisation of work and work environment” is working continuously to find answer of these primary questions. Contradictory objective would have been placed before the researchers to testify the thesis. Saying one task is given to human and same to the relevant machine. Both have been fulfilled in correct way. What could be the conclusion if there is no relevancy between the given task and its performing agent? If measurement parameter is the productivity only, then why a machine should be considered smarter when simple human being is performing same task without any stress and difficulty. “Alternativity” is the central idea of discussion here to judge and assess the usability or usefulness of machine or human being and vice versa.

Developing an alternative menu structure, for a PDA screen is challenging job, it becomes innovative when used by a group of people who perform some organisational task and found it easier and relevant to their job. Similarly, if simpler interface provides easier access to various sections of society and for people of different age groups, Is it social competent? Social competence may be a bigger area to explore and can regress our focused research interests, however social competency of a technology indicates to the acceptance level among wider section of the society. Finally, social compatibility of a technology and their implications to MTO indicates towards human and task to be performed. Organisation sets up task priority, while human requires easiness to perform these tasks. On the hand, when human beings sets up priority for their easiness, it may not be possible for an organisation to design only easy tasks. However, to find a balance between man and organisation, experts shout to design socially compatible technologies. The achievement of socio compatible technology was made possible through the design of these technologies through human centeredness (compare with Ulich E., 1993). Developing a technique to complete the task to a greater degree of easiness without compromising task priority can then only be achieved by giving emphasis on human who are ultimately performing these tasks.

1.7 Human centeredness of technology

One can say my proposed work is more or less partly within the human-centered alternative of designing systems and technologies. This alternative is rooted in the European tradition of human centeredness, which emphasises the symbiosis of human capabilities and machine capacity. The human- centered tradition celebrates the diversity of human skill and ingenuity and provides an alternative to the 'mechanistic' paradigm of "one best way", the "identicalness of science" and the "dream of exact communication". This alternative vision has its origin in the founding European human-centered movement of the 1970's. This includes the German movement of humanisation of work and technology, the Scandinavian movement of democratic participation, and the British movement of Socially Useful Technology. The core ideas of human-centeredness include human- machine symbiosis, the implicit dimension of knowledge, the system as a tool rather than a machine, dialogue, participation, social shaping and usability. Past years theses ideas have become central to various design methodologies, ranging from the socio-technique, social ergonomics, user centered design, user-involved design, and more recently, computer supported cooperative working, informated work environment, human- computer relations, multimedia information system and cognitive technology.

Discussion: *MTO and germen perspective of human- centeredness*

As compared to human-centered research practice of academia in Scandinavia and Germany being an integral part of the mainstream industrial culture, the British research tradition remains rooted into the techno-centric concept, and human –centred system research until now has remained at the outside edge. Von bandemer et al. (1991) suggests that probably the most important institutional factor that has shaped the development of anthropocentric way of working in Germany has been work councils co-determination right in matter of work design. Co-determination provides German employees and their representatives the most far reaching participation rights in the matter of evaluation and regulating the integration of technology at the work place.

One of the key assumptions of this human centric strategy for the use of technology is that skills and competencies of the workforce is a major source innovation, flexibility and productivity, and have become determining factors for meeting the increasing demand for quality and user/consumer orientation.

It is also interesting to note that the Swedish idea of "semi-autonomous group work" challenged the old German craft tradition of "Meister", because the middle and lower management feared losing "power, privileges and even job by the decentralisation of decision and control". Nevertheless, it indicates only the human –organisational behaviour and technology is still apart from the perspective dimension. What more important is that to conclude a meaningful notion which human-centeredness promotes is that of the humans as both the producer and user of knowledge. It seems that this notion stems from the idea that the skilled worker is both the producer of products and the user of products. The worker therefore is not just the producer and user of products and knowledge, but also the evaluator of production, product and knowledge.

What makes it relevant and meaningful if one chooses to write a research thesis on a complexity issue (say interface of PDAs) exploring underneath principles of MTO? Here PDA is merely a technical asset and of course could be replaced by many other instruments, MTO is merely a conceptual foundation and replaced with other academic theories similarly to write a thesis is merely a thirst to accommodate knowledge viewing the things with different perspectives and practices.

If PDA is just an instrument to perform a task and task is simply an activity within the organisation, the interface between the performer, the place of action and by what means he performs must be seen to analyse symbiosis between all the components involved. It brings a condition where human, technology and organisation all coming into existence with their relevant participation. In future if an organisation decides to equip his entire employee with a PDA to perform a certain task or part of it, what makes more interesting to investigate the mechanism of interaction in terms of usefulness of a technology or organisation or participatory interest of human beings involved.

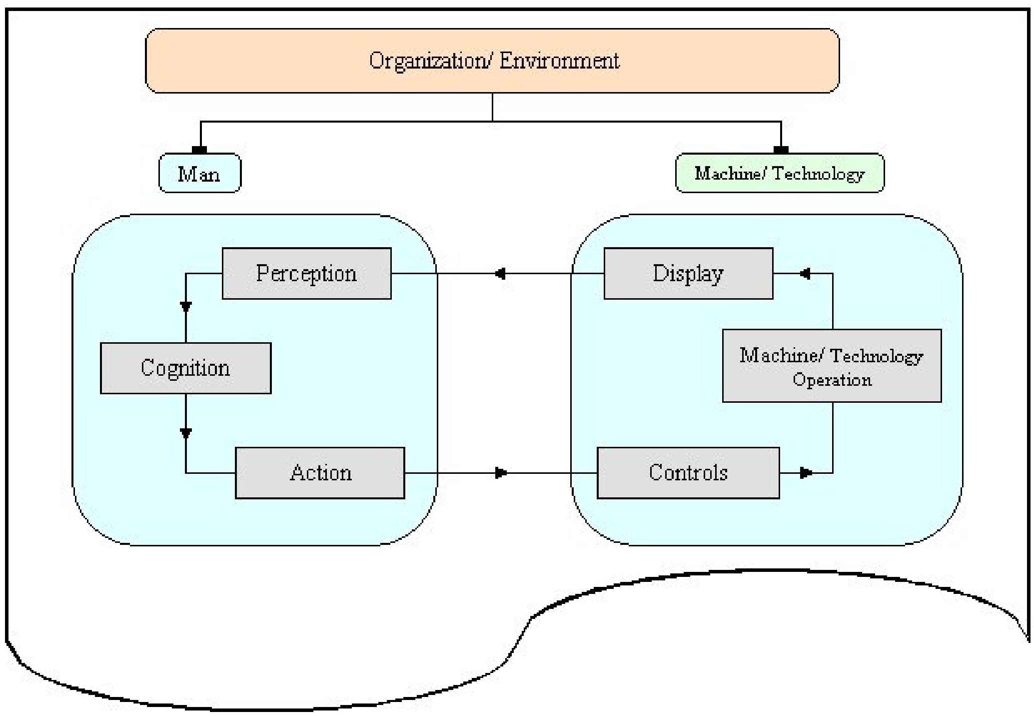

Figure 1-3 Two-way man-machine interactions

As shown in Figure 1.3 an organisation is primarily comprise of two entities namely man and machine who interact together for somewhat known as productivity. However organisation when combined together with man and machine, allocate meaningful tasks to both of them. Now, **machine or technology** offers capacity to perform the **task** by its back end operation. At the front end, technology offers a communication mechanism through **display** (or buttons, levers, handle etc.) and provides **control** to regulate the machine. At the same time, man at other side of operation being equipped with cognitive skills (**cognition**) performs **action** according to their **perception**. It is whether a PDA, the interaction follows the same fundamental principle. User's front-end skill like "*perception*" and "*action*" communicates with machines front-end facility of providing communication "*display*" and "*control*" over it.

From the early calculation-intensive tools that were prevalent in the 1970s, computer based systems are progressively becoming tools for communication, collaboration, and social interaction among groups of people. In the same way, the context of use is changing. The traditional use i.e. scientific use by the specialist, business use for productivity enhancement, is increasingly being complemented by residential and nomadic use, thus penetrating a wider range of human activities in a broader variety of environments, such as the school, the home, the market place, and other civil and social context.

There are critical shortage of empirical studies on information systems problems and constant calls in the scholarly literature for more in depth research. The proposed study tries to provide a piece of information about the interface complexity of ever becoming small devices. This is an experiment based- empirical study of the user and on the use of personal digital assistants. As described in previous paragraphs the whole study is designed under the umbrella of man- technology- organisation relationship. It has been emphasised that under the organisational roof the relevance and meaning of using technique is a matter of great consideration whether it is proving usable and useful to perform certain task.

The study covers at least three different disciplines in the wide area of interaction research: work and organisation psychology, mobile –human computer interaction, and human centeredness. Finally, it converges towards answering the specific questions relating to the use of menu structure in PDAs only.

This study can be useful for the organisation planner if he is engaged in planning of decentralizing the unit, it can be useful for the interface designer to consider the interaction issues with such a small device further various terminal interfaces are also the interesting area to be benefited by this study.

1.8 Research background and justification of the study

The quality of man machine interaction is critically limited by the lack of soundly based psychological knowledge of the human element in the interaction.

Much of traditional human factors research is applicable to this area. Developed as a study of man- machine interfacing with a strong engineering bias it lacks validity in a situation where man no longer merely operates on the device but rather enters into the communication with it. This requires a much more psychological foundation. Knowledge of human problem solving skills and comprehension, information processing capacity, memory, cognitive style, motivation, learning and personality variables are all-essential to understand the nature of man machine interaction. Similarly, it is important to understand user's need and attitude and to empirically clarify how these effect performances and change over time. It cannot be hoped to design "user friendly" systems without resources at some stage to psychological principles.

One source of tremendous confusion has been an inability to define the "systems" of interest. From one point of view, the computer program being executed is the end application of concern. In this case, one often speaks of the interface, the task performed within the syntax of the interface, and human users of the interface. Notice that the application world (what the interface is used for) is de-emphasized. The bulk of human- computer interface takes this perspective. Issues of concern include designing for learning ability i.e. performance (Brown, 1982; Carroll & Carrithers, 1984; Kieras & Polson, 1985), and designing for ease and satisfaction of use (Norman & Draper, 1986; Malone, 1983; Shneiderman, 1987)

A second perspective is to distinguish the interface from the application world (Miyata & Norman, 1986; Stefik et al. 1987; Rasmussen, 1986). The interface is an external representation of an application world, that is, a medium through which agents come to know and act on the real world problem.

The identification of relevant user interface properties is to be checked. The properties should be general enough to fit different application domains of small devices and, at the same time, should be able to take into account some specific requirements of the application domain considered. According to Holmquist (1999)

> *"Designing user interface for small screen is a difficult problem, much more difficult than it may seem at first glance. We cannot simply take established interface conventions and shrink them to baby face size, because just like children have a unique way of life, baby faces are different to desktop computers in ways that we are only beginning to comprehend"*

Another strong argument to justify the present study for small screen device is the lack of academicals research. If we look around our common household items, we are practically immersed with small interfaces6. As an estimate in an informal poll, each household has small interfaces ranging 6 to 20. Kutti (1999) found

> *"Surprisingly enough, for the academical HCI- community these small interfaces do not exists, or at least the community has not published practically anything about them in CHI- conferences or in major HCI journals"*

When compared against their penetration in our lives and the non-standard nature of small screen devices it is rather justifiable to research on the issues where users are supposed to be directly benefited.

1.9 Outline of the thesis

The thesis is organized in 9 chapters in a sequential manner. Chapter 1 introduces the intermediate level background information on the related disciplines that are contributing their input to the current research. It has been tried to make it clear the conceptual content of the research problem. This chapter serves the purpose of awakening interest and providing structured content to the reader. Chapter 2 is solely devoted to the details on handheld devices with special reference to personal digital assistants and its user interfaces. The author tries to enter in the topic of interest and giving overall view for which the study has been evolved. This chapter also gives an overview of the complexity issues on the technical side of technique. Chapter 3 is stating research problem regarding the use of menu in detail. This chapter is raising and discussing the questions, which have to be answered during the whole span of study. Chapter 4 is devoted to the theoretical part of the research. In this chapter general term and theoretical basis of research is clarified, consequently these theories have been employed to test the hypothesis. Apart from giving its basic relevance it has been critically examined to fit correct enough for the research intentions. Generated hypothesis and assumptions made for the research are described in Chapter 5. Chapter 6 describes about the methodology used for the study it includes details on metrics & measurement, Prototype simulation, Questionnaire and Experimental design. Chapter 7 provides research investigation details, Evaluation, analysis and explanation of the results Chapter 8 is summarizing the research outcome. Chapter 9 makes discussion on conclusion-and stating research contribution to academics and usefulness in practice.

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6 CD player, video recorder, television, calculator, microwave oven, mobile phones, PDAs etc.

1.10 Summary

Ability to convey ideas like human to human does not work well when humans interact with device like PDAs. This is due to limitations involved in both. We are here concerned with limitation of a small screen display device, namely interface complexity. Interface complexity found to be an underneath problem of interaction aspect. Since complexity of interface is primarily understood as an interaction problem between humans and computers. HCI seeks to produce user interfaces that facilitate and enrich human motivation, action, and experience, but to do deliberately it must also incorporate means of understanding user interfaces in terms of human motivation, action and experience. However, it is clear that varying what is meant by interaction, human, and machine leads to a rich space of possible topics. Interaction with mobile devices would wish to identify as more central. Since last few years considerable research are being conducted related to small handheld devices. There is still lack of research in complexity issues of menu arrangement in small screens. However, the constraints in screen size and form factor also favour menu-based dialog over a mouse based graphical user interface. Initially there were no guiding principal separate for these small devices, as more and more technological advances came these devices has taken scientific principles applied those for desktop computing devices. It is also seen, however, spectrum and field is still not fully explored in case of mobile devices, and university level research is taking pace to investigate more on the issue of interaction styles with mobile devices. Based on the socio-technical consideration, organization can be added to traditional HCI research and we formed man-technology-organisation elementary model of our research interest as conceptual foundation with a view that "it cannot be ruled out for some task in an organisation humans may better perform with alternative techniques". It is therefore, technology, user and organisation together constituting a meaningful basis for researching these interdependent entities. The concept presented here does not refer predominantly to the changed quality of human data processing for the regulation of socio-technical consequences of the computer technology and further its effect to cognitive structures of human communication and the man-machine-organization. It deals with the possibility of introducing such technology in an organisation for the humans working there in particular kind of task, in a way that all the three elements (man, technology and organisation) might be profited largely. Social compatibility of a technology and their implications to MTO indicates towards human and task to be performed where, organisation sets up task priority, while human requires easiness to perform these tasks. The achievement of socially compatible technology can be made possible through the design of these technologies through human centeredness. Therefore, the identification of relevant user interface properties is to be checked. Overall, it can be summarised that, research on alternative menu (non-linear) and comparison with linear menu in modern handhelds are then valuable and significant.

Chapter 2

Handheld device and user interfaces

2.1 Introduction

Mobile computing, now an established and recognized field appears to become the prevailing computing paradigm. Becoming visible in many forms and with increasingly diverse functions, handheld devices now include personal digital assistants such as the palmOS and pocket PC, handheld games like game boy, mobile phones, digital audio players, smart cameras, and many more. Developers are enhancing these handheld devices with continually increasing functions that are not only crossing boundaries, such as GPS- enabled PDAs and games or cameras on phones but also the use of PDA-class devices are attaining a critical mass in schools, hospitals, railway services and other venues beyond conventional business uses. Communication technologies such as Bluetooth, WiFi, and G3 are making it easier for these devices to communicate with other handhelds, appliances, and computers.

Handhelds are rapidly becoming ubiquitously accompanying buddy that support activities of every day life. Faster processing, increased storage, and improved interconnectivity make this device useful as universal entertainment equipment, electronic map and guidance systems, and access device for information retrieval from the web or specific information systems such as tourist guides.

This chapter describes handheld devices, its development and architecture under both the software and hardware aspects. As the author is mainly concerns about menu structures in PDAs, content of the chapter is organised primarily on PDAs. To understand handhelds, it is essential at first to identify their place on the scale of the personal computing device- and their place within portable consumer electronics. Handheld devices are analogous to desktop computers in a way that both involve computation, information management, and communication.

2.2 Definition of handheld device

Small screen devices are available in different size and specification. They range from portable CD player to small laptop. We consider it, as handheld devices are portable, self- contained information management and communication devices. An apparatus must pass following three specifications to be considered as a handheld device:

- It must operate without cables, except temporarily (recharging, synchronizing)
- It must be easily used while in one's hand, not resting on a table
- It must allow the addition of applications or support Internet connectivity.

Handhelds are smaller, lighter, and less capable than desktop computers. Nevertheless, they offer portability and instant access to time-critical information as tradeoffs. Nomenclature is always a challenging job in any new area of technology. There are many synonyms of such a device: quite often-used terms are wireless, mobile, portable etc. I am using the term "handheld" for the ease of classifying small computing devices.

2.3 Features of handheld devices

2.3.1 Portability

A short walk through the Akihabara electrical town in Tokyo (www.akiba.or.jp) reveals the latest trend in handheld devices with large variations from high-end PDAs to integrated portable unit containing functions ranging from MP3 player to GPS navigation. Their key advantages include portability, sole ownership, and privacy.

If we consider the development scale according to portability of device, we can conclude it as shown in the figure 2.1

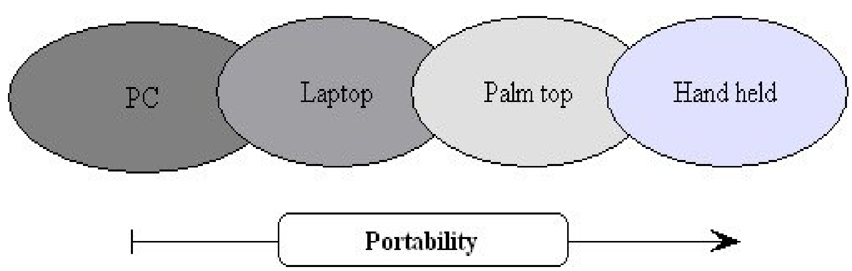

Figure 2-1 Portability of computing devices

Size decreases to the right as portability increases. Desktop computers at the far left are stationary devices and require both power and connectivity. A laptop computer enables mobility, but they are heavy and must use on a table. They work best when connected to a power source, and most laptop users travel with telephone or ethernet cables to connect to corporate networks and the Internet. Palmtop looks like laptop and are significantly smaller often fitting into a size of pocket or purse. At the far right are handhelds, which functions best while held in the hand. Handhelds can be further subdivided into three: namely PDAs, mobile phones and pagers. Interestingly intersection of all these are best fit to the device like communicator, which has few characteristics of all the three.

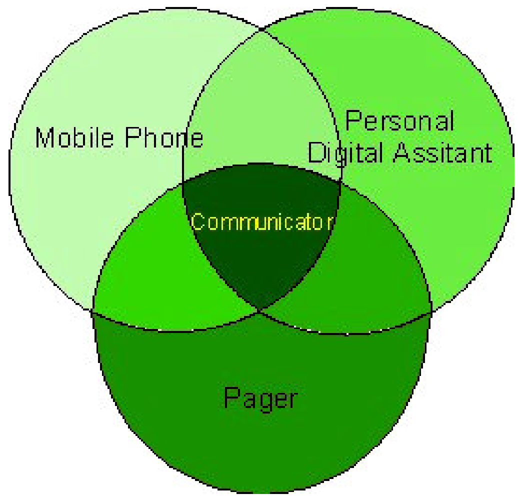

Figure 2-2 Intersection of three common handheld

2.3.1 Interoperability

Developers of handhelds have already explored symbiosis to overcome some limitation and recognised, as symbiosis will be a key component for handheld survival (Myers, 2001; Narayanaswami, 2001; Went, 2002). The link between PDAs and larger desktop or laptop computers offers a fine example of interoperability. The desktop's full size keyboard and larger display simplify the management of data and application on the linked PDA. The synchronisation between the two devices simply and safely backs up the PDAs data. Additionally if we consider ease of use and availability of application, symbiosis with personal computers gave PDAs an obvious advantage over simple simpler address books.

> ***Critical discussion :*** *Though Myers, Narayanaswami, as well as Went have thrown wider light on significance of PDAs while indicating symbiosis is to be considered as key component for survival of PDAs, here one must also consider the rapidly developing peripheral technology which enables these small device fully competitive with traditional desktop. Several prototypes use tiny, low power, vector based laser displays to let handhelds project images on surface. For example, VKB*

(www.vkb.co.il) produces a small device that connects to the commercial handhelds and projects a virtual keyboard on everyday surfaces. The system incorporates an infrared detection system to determine when a user has touched the projected keys, effectively empowering a handheld with a full size keyboard.

Handheld devices play a different role than the wired web than they do in the wired world. In the wired Internet, devices are interchangeable. The brand, processor type, and amount of memory do not really affect the ability to connect to the Internet. Mobile devices vary greatly in display size, keyboard, operating system, and processing power so that the devices itself becomes an integral component of the wireless experience. In many ways, the role of mobile devices in application delivery is similar to the computing world of 1980s when application were intimately tied to specific kind of displays such as IBM 3270[7] terminals, x-windows[8], and PCs.

Devices are the entry point into the communication world. The evolution and convergence of computing power and telecommunications, along with improvement in semiconductors and display technologies, has led to an outburst of new devices and options for wireless internet connectivity as well. Worldwide, about 30 million PDAs are in use, but this pale in comparison to the 1.3 billion mobile phones currently being used[9]. Increasingly these mobile smart phones offer PDA-like capabilities. As an estimate, in 2003 smart phone sales were reach 4 million units in Europe, for the first time outpacing sales of PDAs[10]. The IDC predicts that market of smart hand-held devices will grow from 12.9 million in 2000 to over 63.4 million by 2004, creating an opportunity worth $26 billion[11]. In the US, prediction indicate that the smart phone segment of the phone market will increase from 8.5 % in 2003 to 35 % in 2007, while PDA sales will increase from 6.9 million to 17.1 million in the same period[12].

However, wireless adds the freedom of place and time to the internet experience; user's interaction depends on the device they use. Cell phones, PDAs, and hand-held computers are steering mobile commerce, extending the enterprise, and

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[7] IBM 3270 is a class of terminals made by IBM known as "Display Devices", normally used to talk to IBM mainframes. The 3270 attempts to minimise the number of I/O interrupts required by accepting large blocks of data, known as datastreams, in which both text and control (or formatting functions) are interspersed allowing an entire screen to be "painted" as a single output operation

[8] X-Windows A common misnomer for the X Window System. (1997-06-10). X Window is a windowing environment for workstations that provides significant efficiency and power to users. X Window supports graphics display and is based on the client/server model.

[9] Retrieved from http://www.cellular.co.za/stats/stats-main.htm on 21.07.2003

[10] Retrieved from http://search.internet.com/www.rimroad.com on 23.07.2003

[11] Retrieved from http://www.idc.com/Hardware/press/PR/CP/CP022601pr.stm on 20.11.2003

[12] Retrieved from http://www.wirelessadvent.com/news/2003/169/news7.html on 17.01.2004

opening up new modes of entertainment. As these devices move towards each other in form and function, network bandwidth will increase, further driving new device designs.

2.3.3 Convergence

Figure 2.3 illustrates the convergence of wireless devices along two lines of development- the voice-centric handheld phones and the computers. Handheld phones evolved from their first-generation analogue origins to device capable of both digital voice and data. Developments on the computer side have been driven by the need to combine functionality within the constraints set by the small form factor of portable device.

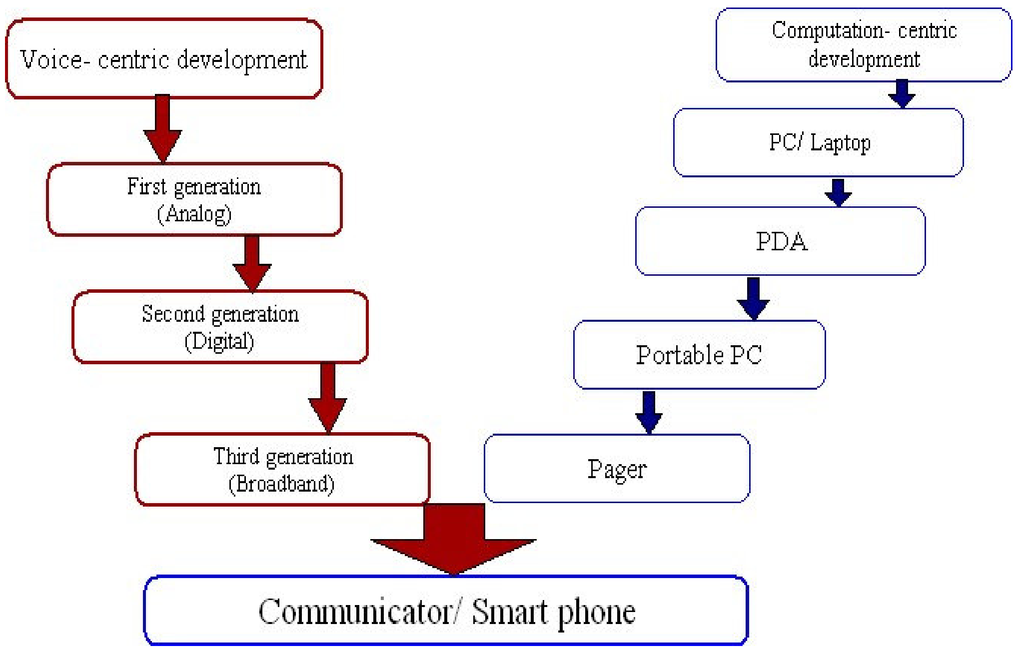

Figure 2-3 Convergence of communication mode

Wireless trades off mobility for interface. Because wireless users want both portability and utility, mobile phone and PDAs are adopting smaller footprints and driving down the size of keypads and displays. However, the price has to be paid for that: the smaller the screen, the less information is displayed at any one time, making the user interface central in application delivery.

2.4 Device profile

Handheld devices can be divided into four distinct categories: Mobile phones, PDAs, pagers, and portable computers are available in a wide range of screen sizes, keyboards, and computing power. The choice is the requirement of the end user's standpoint of both quality of user experience and the need for supporting network infrastructure. Phones are primarily used for voice communication, pagers are primarily used for two-way email, and PDAs are primarily used for personal information storage and retrieval. User experience may vary from a simple black-and- white text display to a rich full colour multimedia experience. PDA like computational device has the computing power and memory to stand-alone and delivers offline services to users. Such device requires only limited wireless access to networks because data and programs can be downloaded into a device, after which the device can run on its own.

Apple Computer gave the term **personal digital assistant** with the introduction of product named Newton. As per definition, "*PDAs are the small hand-held computing devices designed to provide organizational tasks, including electronic calendar and contact database function*". Day by day competition among the developing industries PDAs are available in different operating systems and extended capability.

PDAs are feature rich stand-alone devices that have at least address books and calendar functions. All PDAs have touch screens and use a stylus for input, although some PDAs are coming with QWERTY keypads[13] and styli[14]. The majority of PDAs support email, to-do lists, note taking, and desktop synchronisation. Almost all PDAs allow developers to write native applications for them in their respective operating systems. Latest PDAs also supports Internet connectivity features via internal or add-on hardware.

PDAs are typically larger and heavier than phones. They range from just over 4 ounce to over 7 ounce. They come in vertical or horizontal layouts as clamshell or always open models. The largest PDAs are a little smaller than palmtops, while the smallest one is slightly larger than mobile phone. Palmtops are not PDAs, although they closely are similar to them. Palm tops have larger display and they are best used on a table instead in one's hands.

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[13] QWERTY is the modern-day layout of letters on most English language computer keyboards and typewriter keyboards. It takes its name from the first six letters shown on the keyboard's top row of letters.
[14]the term "stylus" (Pl. Styli) often refers an input method usually used in PDAs. In this method, a stylus that secretes no ink touches a touch screen instead of a finger to avoid getting the natural oil from one's hands on the screen.

Device Class	Palm	Pocket PC	Handheld PC	EPOC PDA
Products	Palm IIIx/ IIIc/V/VII (Palm), Visor (Hand- spring), Workpad (IBM)	Jornada 540 (HP), E-115 (Casio), iPaq H3630 (Compaq)	Aero 8000 (Compaq), Jornada 820 (HP), MobilePro 880 (NEC)	Serie 5mx pro/ Revo (Psion), MC218 (Ericsson)
Operating System	Palm OS	Windows CE 3.0	Windows CE 2.11	EPOC
Size	8 x 12 x 2 cm	13 x 7.8 x 1.6 cm	25 x 20 x 3 cm	17 x 9 x 2 cm
Weight	140 – 160 g	255 g	1 – 1.3 kg	200 – 350 g
Data Entry	Stylus	Stylus	Keyboard	Keyboard
Display Type	monochrome or 256 colors touch screen	65000 colors touch screen	65000 colors touch screen	monochrome touch screen
Display Size	7.8 cm	21 – 25 cm	21 – 25 cm	12 – 14 cm
Display Resolution	160 x 160 pixels	320 x 240 pixels	800 x 600 pixels	480 x 160 pixels
RAM	2 – 8 MB	16 MB	16 MB	8 – 32 MB
Battery charge	> 10 hours	8 hours	4 – 10 hours	> 10 hours
Peripherals	Serial, Infrared, Springboard (Visor only)	Serial, USB, Infrared, Compact Fl., Voice rec., Audio speaker,	Serial, USB, Infrared, PC Card, Compact Fl., ext. display	Serial Port, Infrared, Compact- Flash
Applications	PIM, HotSync, Graffiti	PIM, ActiveSync, Handwriting recognition, Internet Explorer, Office Suite, Media player	PIM, ActiveSync, Handwriting recognition, Internet Explorer, Office Suite	PIM, Internet Browser, Database, Spreadsheet, WAP (MC218 only)

Figure 2-4 Comparison of handheld computers and sub- notebook

For the shake of exactness of our study, we will utilize the definition of PDA as ***"a handheld device capable of running stand-alone application and comprised of a user interface environment which facilitate user to interact with the device by the means of some form of menu"***. Stand-alone application refers to a programme, which is not the part of standard built-in utility programme (such as address book, to- do list etc.) but to the programme which can be installed into the device according to the need of an individual user. These programmes or applications utilising the features (like menu) made available through user interface environment to the users. To the next, we discuss available user interface environment in modern handhelds or PDAs.

2.5 User interface environments

There are two most popular user interface environment for PDAs: Windows CE[15] and Palm OS[16]. Windows CE takes the desktop user interface and shrinks it to fit on the PDA screen, while the Palm OS environment was designed as a PDA user interface from the outset, taking only the features absolutely necessary to include in a PDA.

2.5.1 Microsoft windows CE

Microsoft has written one operating system for all "consumer electronics" devices, called Windows CE. They are coming in three flavours to deploy in pocket PC, handheld PC and smart phone. Windows CE is a 32-bit multitasking operating system scaled for handheld devices. Nevertheless, it operates like a miniaturised version of windows, making it burdensome to use on a small display without a full keyboard.

Figure 2-5 Windows media player in windows CE

Windows CE supports a central file system, enabling users to do housekeeping chores easily and enabling application developers to rely on this user interface to manage their document effectively. Windows CE applications feature a well-known menu bar (non-linear), positioned at the bottom of the display.

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[15] Operating system for small handheld device owned by Microsoft Corporation
[16] Operating system for PDAs owned by Palm Inc.

2.5.2 *Palm OS*

The palm OS user interface environment was introduced in 1996 with the release of the Palm™ pilot handheld. In fact, it was an upgradation of available PDAs, mainly Apple's Newton by stripping away from the design. However, the palm OS main operating environment still looks and feels like the first version, it is simple to use, but its functionality is limited. It lacks a central file system, which requires users to look for data application by application, rather than from one location. The lack of central file system also makes housekeeping a particular unpleasant task on Palm OS, as there is no one place to look to delete not needed files. However, software vendor DataViz® has extended file system capability by providing "Document To Go" product, though it restricts this facility only within the "Document To Go" application.

2.5.3 *RIM for the Blackberry*

RIM (Research In Motion) provides a proprietary operating system (OS) for the Blackberry, which makes heavy use of the device's specialized input devices, particularly the thumbwheel. The OS provides support for MIDP[17] 1.0 and WAP 1.2. Previous versions allowed wireless synchronisation with Microsoft exchange server's[18] e-mail and calendar, as well as with Lotus Domino's[19] e-mail. The current OS provides a subset of MIDP 2.0, and allows complete wireless activation and synchronization with Exchange's e-mail, calendar, tasks, notes and contacts, and adds support for Novell GroupWise[20].

2.5.4 *Symbian OS (formerly EPOC)*

Symbian operating system is designed for mobile devices, with associated libraries, user interface frameworks and reference implementations of common tools, produced by Symbian Ltd. There are a number of smart phone user interface

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[17] Mobile Information Device Profile (MIDP), is a specification published for the use of Java on embedded devices such as cell phones and PDAs

[18] Microsoft Exchange Server is a messaging and collaborative software product developed by Microsoft. It is a part of their Windows Server System line of server products. The use of Microsoft Exchange is very widespread in large corporations using Microsoft infrastructure solutions. Among other things, Microsoft Exchange manages electronic mail, shared calendars and tasks, provides full support for mobile and web-based access to information, and can support very large amounts of data storage.

[19] Lotus Domino is an IBM server product that provides e-mail and collaboration capabilities. Domino began life as Lotus Notes Server, the server component of Lotus Development Corporation's client-server messaging technology. It can be used as an application server for Lotus Notes applications and/or as a web server.

[20] GroupWise is a collaborative software product from Novell offering e-mail, calendaring, instant messaging and document management.

platforms based on Symbian OS, including open platforms. Symbian OS's major advantage is the fact that it was built for handheld devices, with limited resources, that may be running for months or years.

2.5.5 Open source OS

Many operating systems based on the Linux kernel - free (not owned by any company) these include:

2.5.5.1 GPE - Based on GTK+/X11

The GPE palmtop environment or simply GPE aims to provide a Free software GUI environment for palmtop and handheld computers running the GNU/Linux[21] operating system. GPE is not a single piece of software, but a complete environment of components, which makes it possible to use a GNU/Linux handheld for tasks such as personal information management (PIM).

2.5.5.2 OPIE/Qtopia - based on Qt/E

Qtopia is developed by Trolltech. OPIE is a fork of Qtopia developed by volunteers OPIE (Open Palmtop Integrated Environment), a completely open source based graphical user interface for PDAs and other devices running Linux. Qtopia is Trolltech's application platform for embedded Linux based PDAs, mobile phones, web pads, and other mobile computing devices.

2.6 User interface in PDA and it classification

The term "user interface" is frequently used in software design and HCI, however it is not clearly defined for what exactly it used for. According to on-line dictionary of computing (27.09.2003), User interface is defined as

> *"The aspects of a computer system or program which can be seen (or heard or otherwise perceived) by the human user, and the commands[22] and mechanisms the user uses to control its operation and input data"*

It has been seen that different streams of HCI and software engineering are using this term according to their ease of understanding, e.g. software developers understanding the term user interface as the individual screen content whereas

[21] GNU/Linux is the term promoted by the GNU project and its supporters, in particular by its founder and main activist Richard Stallman, to refer to the Linux operating system.

[22] A character string, which tells a program to perform specific action. Most command takes arguments, which either modify the action performed or supply it with input. Commands may be typed by the user or read from a file by a command interpreter. It is also common to refer menu item as commands.

ergonomics defines it as the physical part of the machine, equipment or device by which user is interacting. As per meaning of the word "interface" is nothing but an entity or boundary between user and the machine. In HCI, problem of user interface arise due to complex nature of computing principle running behind the application. Therefore, sometimes it is denoted as a 'program' that controls a display for the user to interact with the system. It is easy for ergonomics personal to understand and define interface if he is talking about a simple "mechanical lathe machine" as it contains only mechanical part. One can simply say the switch or roller handles etc. are the *interface* by which the user is operating or communicating with the machine to perform the job. What will happen if this lathe machine is equipped with CNC[23] system? It adds an embedded system and display where user is feeding programme to operate in addition to perform the job manually direct with the machine. As per the definition quoted above, naturally, display screen provided with lathe machine become the user interface, because operator is controlling the operation through the menu displayed. In this case, physical parts of the machine are less relevant as far as the user interface is concerned. However, they provide also a means of communication between user and machine.

In the same way, PDAs consist of hardware and embedded/ operating software, which force one to understand user interface in two different dimensions: hardware interface and software interface. Therefore, we need to classify interface available in a PDA to avoid confusion in understanding user interface and their parts.

As stated above we classify PDA user interfaces in two i.e. hardware and software (tangible and intangible). Hardware user interface are those, which have physical characteristics, can be touched or felt by user while interacting with the device. Examples of those hardware interfaces are buttons, stylus pen and accessories. These hardware accessories are tangible in nature and can be damaged, destroyed or lost. On the contrary, software user interfaces are intangible in nature, resulted from a programmed set of instructions. As I am concerned about software user interfaces, this is further classified into common, service and application. Common interfaces are in-built in PDA, e.g. info label. Device itself has control over these interfaces. These have very important and fundamental functions to give some basic information (like time and date) and feedback (alert message). Service interface are those pushed by

[23]Computerised numerical controlled

remote server or service provider. Example is a browser interface. However, browser is also a stand-alone application; we classify it as service interface in which, we consider content displayed by browser only. Information displayed by browser serves the purpose to provide means of communication and hence placed in service interface. Application interface that is of principle concern in this study, are those resulted from running an application via suitable user interface environment [see 2.5] in the device.

Application interface can be further classified into radio button, forms, text box, scroll bar, menu etc. Since an application may have various features incorporated (e.g. a text editing application requires menu, text box, scroll bar etc.), all these have analogous functions to provide assistance to work with the application. Menu is further categorised as linear and non-linear based on the structural principle of design, we describe it in following paragraphs.

2.6.1 PDA hardware user interface

Like all other handheld devices, PDAs have displays, labelling, and buttons. Some PDAs have silk screened buttons and soft keys.

2.6.1.1 Display

All PDAs have display screen of colour or only black and white output. These displays vary with regard to dimension, ability to display bitmap, colour resolution, and touch or stylus sensitivity. PDA style display can be as large as 300 x 560 pixels, which can result in up to 40 lines of 30 characters per line, but not necessarily- characters can be as small as 5 x 7 pixels or as large as 20 x 20.

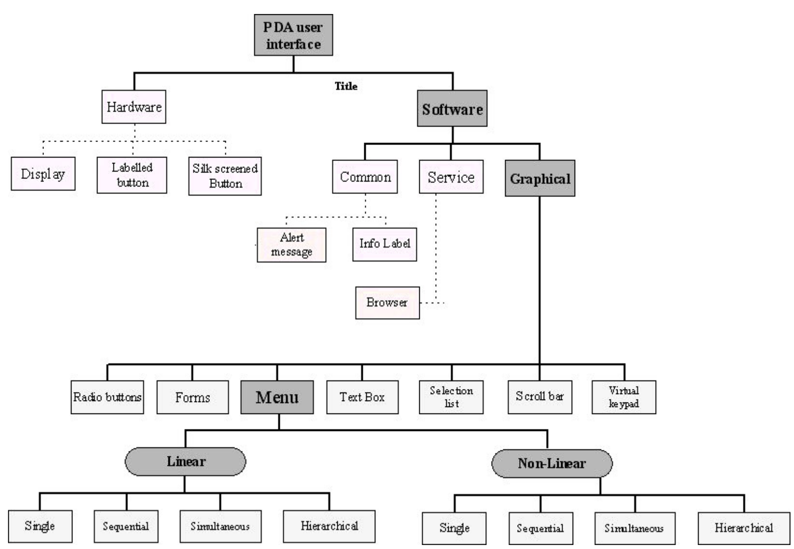

Figure 2-6 User Interface classification

2.6.1.2 Labelled buttons

All PDAs support labelled buttons of some type. Buttons typically contain silk-screened labels, although some button labels are positioned adjacent to the button itself. Normally these buttons produce obvious audio and /or visual feedback.

2.6.1.3 Silk-screened buttons

Silk-screened buttons are graphics or texts that are printed on or under the glass of a touch screen display. These buttons are relatively harder to press than hardware keys, but their forced consistency makes them more usable than on-screen graphical buttons, which have different placement, size and appearance.

2.6.2 PDA software user interface

2.6.2.1 Common user interface

All PDAs have some common user interfaces – these are icons on the very first screen and some in-built system information-displaying button like interface. Icons are serving the purpose of main menu for using the different options and services provided by the system whereas system information displaying icons are giving information about the time, battery status or available resources within the system.

2.6.2.2 Application interface (GUI)

An application program displays certain icons, buttons, dialogue boxes, etc. in its window on the screen and the user controls it mainly by moving a pointer on the screen and selecting certain object by pressing buttons on the mouse while the pointer is pointing at them.

With advancement of different scripting languages and available application windowing toolkits, it becomes easier to develop user interfaces by using graphics etc. According to dictionary of computing

> *"Graphical user interface Uses pictures rather than just words to represent the input and output of a program. A program with a GUI runs under some windowing system[24].*

[24] Windowing system started with the first real time graphic display systems for computers, namely the SAGE project and Ivan Sutherland's Sketchpad (1963). Douglas Engelbart's Augmentation of Human Intellect project at SRI in the 1960s developed the online system, which incorporated a mouse-driven cursor and multiple windows. Several people from Engelbart's project went to Xerox PARC in the early 1970s. The Xerox PARC team established the WIMP (window, icon, menu, pull down) concept, which appeared

Most common elements are the radio button, forms, textbox, menu, scroll bar, selection list and virtual keyboards.

2.6.2.2.1 Radio button

A radio button is a type of graphical user interface widget that allows the user to select one of a predefined set of options. Radio buttons are arranged in groups of two or more and displayed on screen as, for example, a list of circular holes that can contain white space (for unselected) or a dot (for selected).

Figure 2-7 A group of radio buttons, with one choice selected, in Windows XP

Adjacent to each radio button is normally shown a caption describing the choice that this radio button represents. When the user selects a radio button, any previously selected radio button in the same group becomes deselected.

2.6.2.2.2 Forms

A type of user interface used (e.g. in www) to organise a set of questions or options for the user so that it resembles a traditional paper form that is filled out (Foldoc, 2006).

2.6.2.2.3 Text box

A text box is a common element of graphical user interface of computer programs, as well as the corresponding type of widget used when programming GUIs. A text box's purpose is to allow the user to input text information to be used by the program.

A typical text box is a rectangle of any size, possibly with a border that separates the text box from the rest of the interface. Text boxes may contain zero, one, or two scrollbars[25].

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commercially in the Xerox 8010 (Star) system in1981. Beginning in 1980 Apple Computers continued to develop such ideas in the first commercially successful product to use GUI, the Apple Macintosh, released in January 1984. Microsoft modelled the first version of well-known “Windows”, released in 1985, on Mac OS. Window was a GUI for MS-DOS that had been shipped with IBM PC and compatible computers since 1981

[25] A scrollbar, or slider, is a graphical widget in a GUI with which continuous text, pictures or anything else can be scrolled, i.e., viewed even if it does not fit into the space.

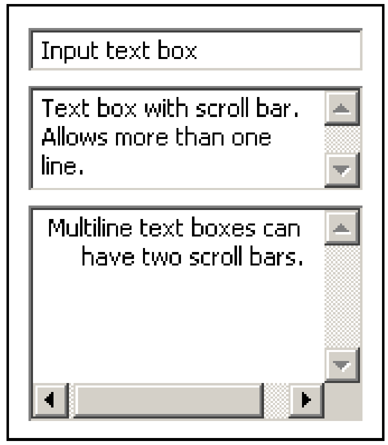

Figure 2-8 Text boxes with different row counts

2.6.2.2.4 Selection list or check box

A check box is a graphical user interface element (widget) that indicates a two-way choice or state (true/false) which can be edited by the user. Adjacent to the check box is normally shown a caption describing the meaning of the check box.

2.6.2.2.5 Scrollbar

See footnote 21

2.6.2.2.6 Virtual keyboard

A virtual keyboard is a feature of a computer program or a program in and of itself that acts as a virtual extension of a controller with fewer buttons than a keyboard would have.

2.6.2.2.7 Menu

Online dictionary on computing – Foldoc (2006) defines menu as a list from which the user may select an operation to be performed. In our classification, there are two-principle division of menu viz. linear and non-linear. This classification of menu adopts the organization pattern of menu on display screen. In computing world, menus are differentiated in several ways like drop down, pop-up and split menu etc. we have classified menu in PDAs based on their organisation (structure) at first. Linear and non-linear menu can be further subdivided in single, sequential, simultaneous and hierarchical.

As name indicates, Single menu referred to single option presented in screen at a time where as sequential refers to option presented in a sequence one after another.

Simultaneous menu are those in which options are available at the same time and hierarchical menu are those in which options are sub grouped and made available in hierarchical order.

Major concepts related to linear and non-linear menu are discussed in chapter "theory" later on this thesis.

2.7 Use of PDA in an organisation

Why PDA is interesting for MTO in our research? It is due to the fact, PDA are the handhelds gaining increasing popularity among the corporate people. However, it is being used mostly for some small but useful tasks (like appointment, notes taking, address book etc.) it can be better utilised in near future as the capacity and functionality both is increasing. If we refer to our discussion [2.3.3], the trend is to congregate communication device into computational devices. To the present status of PDAs functionality, successful endeavours to utilise these in hospitals for doctors to maintain patient' record has been done. Author, self contributed in a research project at the University of Flensburg, where it has been tried to assess, if these small screen devices are useably applied in small-scale industry workers to do their daily record maintenance job. Nonetheless, a personal digital assistant is similar to other industrial appliance used to assist their employee in doing their delegated job. In view of Ulich's opinion in context of man-technology-organisation, where he considered humans as extended arm (to complement the gap of automation) of machine and machine in tool function (to support human ability), eventually PDA is a rather interesting to research *(see 1.5)*. What make it quite relevant, as far as the MTO is concerned, are the user interfaces and most notably its menu structure on which human interacts. Supposition is that, a lenient menu structure could be beneficial for both the inter-linked side of a technology i.e. man and organization. However, it cannot be generalised for all organization, there are PDAs or plenty of PDA like interfaces being used in many organization. More is discussed in nest chapter "*research problem statement"* of this thesis. The objectives and out come of this chapter is as summarised below.

2.8 Summary

In the previous paragraphs of this chapter, it has thoroughly been explained about the small screen device technology, handheld operating system and finally to the classification of the PDA user interfaces. Classification of handheld user interface serves the purpose to know exactly about what actual part of user interface we are concerned.

Handheld devices are analogous to desktop computers in a way that both involve computation, information management, and communication. These are available in different size and specification. We consider it, as handheld devices are portable, self- contained information management and communication devices. I have used the term “handheld” for the ease of classifying small computing devices.

We found that, although the device landscape is in a constant state of evolution, there are another four major categories of mobile devices: mobile phones, pagers, PDAs, and portable computers. The link between PDAs and larger desktop or laptop computers offers a fine example of interoperability. The synchronisation between the two devices simply and safely backs up the PDAs data. In our discussion, we also found that, mobile devices vary greatly in display size, keyboard, operating system, and processing power and user’s interaction depends on the device they use. Handheld phones evolved from their first-generation analogue origins to device capable of both digital voice and data. Because wireless users want both portability and utility, mobile phone and PDAs are adopting smaller footprints and driving down the size of keypads and displays. However, the price has to be paid for that: the smaller the screen, the less information is displayed at any one time, making the user interface central in application delivery.

PDAs are feature rich stand-alone devices that have at least address books and calendar functions. Almost all PDAs allow developers to write native applications for them in their respective operating systems. They are typically larger and heavier than phones. The largest PDAs are a little smaller than palmtops, while the smallest one is slightly larger than mobile phone. There are two most popular user interface environment for PDAs: Windows CE and Palm OS. Windows CE takes the desktop user interface and shrinks it to fit on the PDA screen, while the Palm OS environment was designed as a PDA user interface from the outset, taking only the features absolutely necessary to include in a PDA.

Problem of user interface arise due to complex nature of computing principle running behind the application. PDAs are consisting of hardware and embedded/

operating software, which force one to understand user interface in two different dimensions: hardware interface and software interface. All PDAs have some common user interfaces – these are icons on the very first screen and some in-built system information-displaying button like interface.

This classification of menu adopts the organisation pattern of menu on display screen. Confined to our study, research problem is based to PDA only, by which PDA means a handheld information appliance capable of running graphical user interface. In the next chapter whenever we use the term handheld, it is unambiguously implies to PDA. These PDAs have at least display area on which menu can be arranged linearly as well as non-linearly. As classified in [2.6], menu displayed is our principle concern; other types of interfaces are strictly ignored for the exactness of study. Therefore, three main presumptions regarding the PDA and user interfaces used in our study are:

I. However, there are many handhelds are of small screen size, in this study handheld means only for PDA. Hence, display area of a typical PDA is taken into consideration while lying menu on them.
II. We are only concerned about menu interface (linear and non-linear) that are graphically displayed and are a part of software user interface. These menu interfaces can be of single item or in sequential, simultaneous or hierarchical order.
III. Operating system supports graphical interfaces to be programmed and displayed accordingly.

With the view of MTO, presumptions can be summarised as:

PDA as a tool utilised in doing some organisational task by humans, creating a basis in research for usable, effective and efficient system. User interface of a PDA then is noteworthy to test, as it may have interaction level difficulty with the user. A distinguished classification of user interface is being worked out to asses the complexity level of an interface as far as the menu is concerned.

Due to limitation caused by PDA size and architecture, there is strong need to improve menu structures of an application programme in a view to provide less complicated interaction. We will take this into further discussion in our next chapter to formulate research problems.

Chapter 3

Research problem description

When a thing is new, people say: "It is not true." Later, when its truth becomes obvious, they say: 'it is not important…. " Finally, when its importance cannot be denied, they say: "Anyway, it is not new."

– William James

3.1 Introduction

This chapter is organized in a straight-thinking form of arguing the problem of probable facet. Once started with thesis proposal it has taken a substantial amount of time while reshaping the theme, its appropriateness and relevance to the current associated research streams. Identifying a potential, noteworthy and clearly defined problem is always being the most important step towards offering a conjugative and in depth analysis of the problem underneath. There is no disagreement among thinkers and theoretician that identification of problem[26] is rather important than finding the solution. While dealing out the available resources it becomes a conscientious job to formulate it to the extent of highest scientific level. I choose discussion way of explaining the problem, expanding its span and concluding it with concrete relevancy. We have identified four areas of interest in stating complexity problem of a PDA interface viz.

- Interface is complex in a particular setting of use e.g. PDA used by workers in an organisation (Critical point of analysis in MTO)
- In general use of small interface is not easy (Complexity in use)
- It is not confirmed that, particular kind (linear menu) of interface is useful enough (usability confirmation)
- Linear structure of menu is inappropriate for PDA interface (Structural organization)

The degree of problem definition will depend on information available in terms of appropriate variables, constraints, both quantitative and qualitative

[26] In order to identify the problem one must first identify all the facts present in the problem description. Once all facts have been identified the problem solver can analyze the facts and identify the problem (Eastman, 2003).

objectives. Typically, the problem space in which design optimisation plays a secondary role, following the establishment of a sufficiently well defined problem domain (Parmee, 2002). Interdisciplinary research themes have no difficulty to find common interest spot but often have problem to join them for getting credible conclusions. The later makes the finding more universal and trustworthy not only because of its expanded volume and contained information but most significantly due to its interdependency with each other.

Although much can be gained by analysing usability problems, there is no overall framework in which large sets of usability problems can be easily classified, compared, and analysed (Keenan, 1999). Current approaches to problem analysis that focus on identifying specific problem characteristics (such as complexity or difficulty in use linear menus) do provide additional information to the developer, designer and technology consultants; however, they do not adequately support high-level (global) analysis. High-level approaches to problem analysis depend on the developer/ evaluator's ability to group problems, yet commonly used techniques for organising usability problems are incomplete and /or provide inadequate information for problem correction (Keenan, 1999). Therefore, we will discuss in following paragraphs above-mentioned four categories of problem, which may have an effect on interface complexity.

3.2 Discussions 1: Symbiosis among man, technology and organisation

Knowledge, tool, coordination these three are the laying stone of man-technology and organization functional model. Human being has natural capacity to utilize systematic knowledge; technology is the tool to reach a productive and positive target, whereas organization has an effective job to coordinate rest both to produce maximum or optimum result. Work and occupational psychologist researches it extensively in previous years to understand the phenomenon of effective work design and work processes within an organization (Ziegler, 1999; Ulich E., 1993). It has also been emphasized to see the effects of these three variables, if one is dependent of social environment (Emery & Thorsrud, 1976).

While using a technology in recent years, organisational and structural changes have affected employee's working groups and domains very directly seen from the perspective of boundary work[27]. Decentralised modes of working are often shouted for devices that are mobile in nature and doing partial job. Using PDAs in hospital and ticket inspector in trains are the classical example. Here not only the work environment but also the use of modern technology determines the consistency of MTO dimensions. The organisation today employs a multitude of IT systems and individual technological tools that are largely unconnected, and which support and maintain very different working routines and tasks.

Detmar W. Straub & James C. Wetherbe (1989) investigated organisational impact on information technologies (vice- versa) and found that existing information technologies during that time were **underutilised** because the human interface was too difficult for non- computer-literate users to master. Noting down here considering PC-use metaphor, Detmar W. S.(1989) forecasted

> *"The entry into the marketplace of extremely friendly and natural interfaces-'high quality' interface - managers, professionals, and administrative assistants will find themselves using computers more intelligently and with greater frequency. The nature, efficiency, and effectiveness of their work will, in fact, be altered in such a profound way that we will see greater productivity improvements in administrative processes than have occurred since the industrial revolution"*

These forecasts proved them as IT & C has rapidly developed during 90's and found the place in so called tech-market or new market. Organisational structure and employee's work conditions changed to switch for or to adopt new mode of working using a set of information technologies.

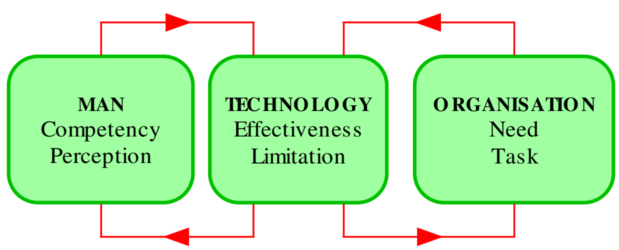

Figure 3-1 MTO relational diagram

To quote past experiences of PC based technology here has only meaning to justify the theoretical ground of identifying the trends in general. Workers in an

[27] First of all, new role definitions between the area managers and their "customers" have caused both internal and external changes. Internally, the area managers have been pushed to reconsider their own roles and ways of working, which have previously been very self-controlled and autonomous, and thereby they have also increasingly been pushed to compare work routines and habits with those of other area managers. This change has been further strengthened by the stepwise introduction of new information technology for filing and sharing work documentation and material, and we will return to this point in the next section. Externally, new questions have arisen in relation to defining new roles vis-´a-vis public institutions (Bødker S., 2003) et al.

organisation with their perception and natural competency could be able to utilise a technique which is meant to fulfil ultimately need of organisation therefore task defined by them. This can be seen in triangular relationship between man-technology-organization building infinitive (∞) relationships, where every parameter is interrelated with each other (see figure 3-1). It is almost impossible to develop a technique which has no limitation, but effectiveness can be optimised if organisational task and therefore need can be better matched with human perception and competency with the alteration of technology.

A user interface in PDA, which is supposed to be complex in one form, can be designed in such a way so that it matches with particular group of human perception and competency. This will facilitate a condition where organisational need is fulfilled and effectiveness of technology is rather increases in spite of limitations.

However, user interfaces will succeed in direct proportion to their ability to approximate normal human modes of interpersonal exchange. Because people are voice and gesture-oriented in their interpersonal exchanges of information, the most “natural” interfaces, therefore, will attempt to approximate human interactions. User-friendly systems, in other words, will gain greater acceptance and have a greater impact in the future (Detmar W. S. & Wetherbe, 1989). As the technology is advancing and it is reaching to every unexplored part of our globe, it is a felt need of researcher and planner to draw more attention on inter-relationship between man-technology and organisation.

Conceptions of a "good system”, for example, a technical specialist interested in working with a state-of-the-art technology, a staff analyst interested in having an easily intelligible instrument, or a manager who is interested in reducing critical costs in his organisational unit. Interactionists view computing as a field in which many participants with overlapping but conflicting interests are brought together-designers, vendors, service suppliers, users, consumers, consultants.

These abstract considerations may best be grounded with a particular example before we embark on our complex tour through the empirical studies of MTO in interface analysis. Consider a hypothetical firm, Electronet, which manufactures several lines of electronic products for commercial and consumer markets. Electronet operates four different manufacturing plants, several hundred miles apart from each other and from corporate headquarters. Each plant produces several product lines, between 2000 units per day and 2000-unit month. Most of the consumer-oriented products are mass-produced with no variations between lots, while some of the commercial items are extensively tailored to allow a dozen options that may be selected by the customer. Some of the manufacturing executives in the corporate headquarters have become concerned about relatively high levels of inventory that are carried by the plants and that the commercial products are often delivered behind schedule. They believe that a "demand-dependent" material-control system, which helps to set inventory based on the actual components that will be used in the items that are planned for production will help reduce the level of ambient inventory and reduce unexpected delays in production schedules. Demand-dependent material-control systems typically require extensive amounts of data manipulation and are sensibly automated if they are to be employed in manufacturing plants. How should the design, development, deployment, use, and consequences of such a system for the staff of Electronet be understood?

Analysts of different persuasions would characterize the situation somewhat differently. The traditional management-science approach assumes that material control is largely a technical matter, and management scientists have developed an array of techniques to design the information flows of such a system. MTO analysts would adopt a different strategy. They note that many computerized information systems that have been 'technically' well conceived have nevertheless failed to be accepted by a variety of organizational actors. They argue that in addition to 'correct' technical designs, computerized systems must be well understood by the different people who are expected to use them and must meet their users' work-oriented needs. MTO approach would identify a wide array of organizational staff members who interact with the proposed information system and believe that it might be possible to construct a workable system that meets both the goals of central managers to improve the efficiency of manufacturing operations and the psychological needs of the variety of staff members who will use it. However, rather than advocate the best 'expert' designs, they emphasize strategies such as low complexity in operation, which would make the proposed system maximally acceptable to all parties.

What kinds of differences do PDA information systems make in the nature of the activities performed by and within organizations? Considering the hypothesis that current PDA interfaces with their complex mode of operation failed to bring any change within the organisation. Then the question arises, what contributes an interface with alternative strategy of bringing down the complexity of interface, in MTO.

Most of the scientists account the computing impacts on organisational life. The focus is given in which simple and user-friendly interface of a technology alters the efficiency or effectiveness of organizations, the work life of participants in the organizations, the ways in which activities are structured, the kinds of control managers can exercise in their administrative domains, and the power of different participants to influence the activities of their organization. As we mainly concerns about the menu structure of a PDA interface, MTO Analysis adopts different perspectives and approach to the questions, "What difference does alternative structure of menu in PDAs make?" Organisational adoption of PDA may not be simply based on economic conceptions of task demands; it may also be influenced by a variety of specifiable social features of an organization, is often the staff of an organization will point to 'technical benefits' such as labour reduction, internal efficiencies, and increased control to justify the adoption and use of such technology tool. These, altogether brings innovation in technology use, betterment in work life and efficient achievement of organisational goal. In particular, the MTO may have significant role that differentiates the use of particular technique (e.g. non-linear menu in small interfaces) in an organisation.

3.3 Discussion 2: What are small interfaces and if they are complex to use?

While talking about small interfaces, first we start the discussion, what they are exactly. "*Mobile devices with small screens are becoming more common and will soon be powerful enough to run desktop software. However, the large interfaces of desktop applications do not fit on the small screens. Although there are ways to redesign a UI to fit a smaller area, there are many cases where the only solution is to navigate the large UI with the small screen. The best way to do this, however, is not known*" (Gutwin C., 2004). Small interfaces are everywhere or one can say ubiquitous. They are ranging from wristwatch to television. In our daily practical life, we are facing everywhere these small interfaces frequently while giving less importance to them. In an informal poll at the University of Oulu, Finland, Kutti(1999) found there were ranges from 6 to 20 of small interface devices among the household of university colleagues. Commonly every household has at least a range of devices such as CD players, video recorder, television, calculators, mobile phones, clock, radio etc. each of these devices are equipped with or made of small interface. Even while driving the car or travelling by train passengers has to confront with these small devices. We are practically immersed in these small interface devices, and if we take the whole population it is not a bold guess to say that they are used more than those in '**real**' computers (Kutti, 1999).

One observational example of (automaticity) using small interface in daily life is while passing through one compartment to other in train or while using *automatic* sliding door in toilet. Here, the ability to perform routine activities quickly, effortlessly, and without conscious awareness is called automaticity (Logan, 1988). Perhaps not in all architecture but some of them are written with “automatic” – author have observed, though these door are perhaps in use since years – passengers stop first before the door and expect that the door will open automatically – because it is written there. After few seconds they realizes that perhaps they have to do something like touch or somewhat else. After using their intuitive intelligence, they succeed to the next – and forget about the complexity of operation. It did not harm them or did not make any big trouble so less attention have been paid for the problem and even not accepted as **to be** the problem.

To understand the complexity of interface, one must understand the subject-object relationship here. There is a slender mistake done by the interface designer here. What is the purpose to write 'Automatic' there in this small interface, when user has to do something or perform some operation there to pass through the door? To write 'automatic' is nothing but a single word menu to interact with the door. Nevertheless, this creates confusion in the mind of user for a small time-slot. This gives wrong instruction to the user because the user expects that as soon as he is stands in front of the door it should open automatically. Instead, to write there 'automatic'if one writes, 'Touch here'[28] makes easy to operate the task without confusion. In this case written expression of a simple- single linear menu shows the issue involved in complexity of small interfaces. Later designer realised this problem and they used 'sensors' to eliminate the difficulty.

[28] Alternate: Touch here to open or any other phrase are the subject matter to discuss within instructional theory so keeping away from the current discussion

Modern public buildings are equipped with various sensors and designers eliminated the instructional menu interfaces. Similarly many small interface devices have complexity in operation but user avoids being busy with those while they are less important in daily life and no big loss is associated with them. However, there is no empirical study performed to see what numbers of persons are using these devices with the full capacity. As an estimate, even many experts to novice user cannot use remote of a simple television set correctly. Apparently, there is no scientific data available of such study. One reason may be it attracts less attention of the researchers as they were just fulfilling the basic interfaces functionality of the system, so more emphasis has been given to developing user handbook or manuals. To reduce complexity of operation emphasis has been given in providing additional help materials instead of improving the interface menus. Plenty of research publication institutions and scientific journal published the research done only on developing user's manual; nevertheless, these manuals are not easy to understand.

Kutti (1999) first realised the ignorance of academic research for small interfaces and listed the possible reason as below

1. The problems related to small interfaces are so trivial that they are not worth mentioning,
2. There are no reason to talk separately about small interfaces because the problem are so similar with those in the PC realm,
3. The problem related to small interfaces are transitory and will rapidly vanish when technology develops,
4. In general, there is no interest and pressure to develop small interfaces further, and thus there is no market for research either

The first assessment does not seems to be reasonable as the small interfaces are not less worthy in daily life but also in hi-tech systems as in case of airplane cockpit etc. On the contrary, it can also be claimed that the limitations set by small dimensions and limited way of interacting makes small interfaces more problematic to design than their large counterparts (Kutti,1999). In fact, it makes even big sense to give more emphasis on these small interfaces, while we are practically immersed with them.

The second assessment does not sound plausible, either. It is true, of course that many of the "golden rules" of interaction design apply to small interfaces as well as larger one. Because of the general nature of rules their utility may be even less with the small interfaces, however (Kutti, 1999). It must also be seen with the view for what kind of job and for which purpose the both are being used. Nature and character of performing the task can be different in the both cases. An inventory made in PC can be difficult to perform in PDAs. We should deal small interfaces with their distinctive mode of operation. Therefore, there is need of applying different set of rules.

Here one must not overlook that user interfaces are external representation of solution software. Having small screen alone is distinguishable problem associated with small interfaces.

It may be interesting to follow the perspectives of software design in small interfaces, only when if they are fitting to the paradigm of traditional software design of its counterpart like PCs. One cannot conclude that small interfaces are always symmetric to the desktops or somewhat large display interfaces. Small interfaces have different dimensions of problem representation and consequently different kind of solution representation is associated. Henceforth, it is necessary to research separately the small interfaces as they have varied dimension of system analysis area.

To the third, the problems related to small interfaces are transitory and will vanish with the development of technology, it is not consistent enough to justify on the scientific platform. Development of technology does not implies to offer always making technology simpler but may also add extended functionality and in turns becomes more complex to use. This hypothetical view does not support the argument that "**not to research**" further on small interfaces but in fact more to make extra endeavours finding out logical argument of their peculiar character of working[29]. It cannot be assumed that any technological advances that will facilitate large interfaces, will automatically offer some benefit for small ones (Kutti, 1999). Therefore, it is unavoidable to develop interface guidelines that are specifically meant for those small interfaces.

To the fourth, there is a dramatic growth in recent years of the personal digital assistant (PDA) market demonstrates that users are willing to put up with small, hard-to-read, displays, limited storage battery life, and cumbersome data transfer, in the hope of achieving truly portable access to electronic data. It is probably safe to predict

[29] Accommodating content in limited space

that only a few years from now, devices available will be dramatically improved. Future generations of PDAs will have higher-contrast, easier-to read displays, they will have greater storage capacities, they will be much faster and run for longer periods of time between charges, and they will be more flexible in how they communicate with each other and with other computing devices. These apparent change awakening gradual interest in many researchers to develop and improve small interfaces of PDAs. One fundamental aspect of PDA interface is menu arrangement. As discussed above it cannot be always established that interface metaphor used in desktop also fit with small screen devices. Menu pattern used in PDA must also be altered to see if an alternative produces better result in terms of easiness in its operation. There may be other representation like iconic arrangement of options laid in non-linear fashion or if the menu still proves useful in case of small screen devices. To the next, we are discussing the effect of screen size on menu selection and user's performance.

3.3.1 Effect of small screen size on menu selection and users performance

In small handhelds like PDAs size of display plays a predominant role while information processing and retrieval. The form factors used for these mobile devices constrain their screens to be only a fraction of what is available on the desktop (See figure 3.3). For example, a 320- pixel by 240-pixel display of a PocketPC system has less than 1/16 the screen area of a 1280x1024 screen, and only 1/25 of a 1600x1200 screen.

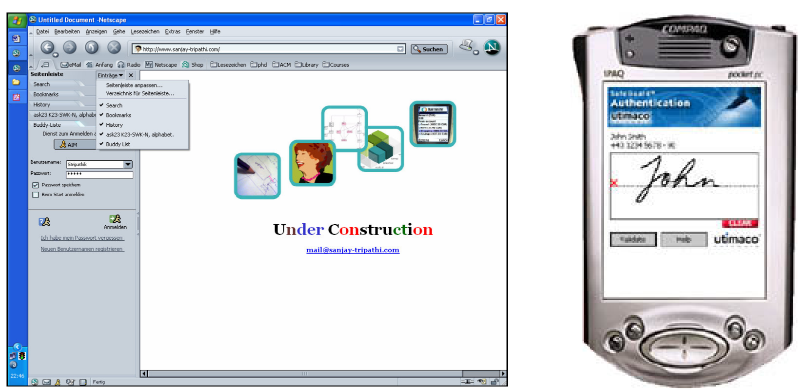

Figure 3-2 Screen size comparison between desktop and PDA

Although the resolution of PDA screens is increasing, limitations on the physical size of the screen will prevent these devices from ever reaching parity with the desktop.

Many interactive applications have complex interfaces that consume considerable screen space. Toolbars and tool palettes help windows, outline views, and status bars all take up space, even without considering the workspace and data. However, there are times when applications cannot be run on a screen that comfortably contains the interface. This problem becomes acute when using mobile and handheld computers such as personal digital assistants (PDAs) or sub-notebooks. Gutwin & Fedak (2004) claimed that, these kinds of systems are becoming more and more common, and will soon have (or already do have) the power to run complex interactive applications.

Interactive applications are menu enriched to enable users with more degree of freedom to use the features. Linear menu designs as in case of hierarchical set of commands are most suitable and commonly used in case of large displays. Screen size alone makes it possible to give more set of organised options to work with application. Nevertheless considerable amount of research has been carried out to improve linear organised menu system for large displays (Shneiderman, 1987).

Kamba *et al.* (1996) stated that the small physical size of a PDA limits the maximum size of its screen, which can be no larger than the dimensions of the machine in which it is embedded. It indicates that there is the need for displayed text to be legible. As a result, it defines another more subtle boundary i.e. if the size of text cannot be reduced below a threshold of readability, then, as the screen shrinks in size, and less information may be shown on it, the user will be required to increase the level of interaction with the device in order to get to desired information.

The general problem of how to deal with those data which does not fit in one single screen is well known problem in HCI. In case of small screen sized devices, it becomes more tedious to deal with. Therefore, menu design for small screen needs more attention and cleverer solutions to get optimum result and user's satisfaction. Some of the iterative techniques as panning, zooming and multiple views have been applied to small screen displays but Gutwin and Fedek (2004) found that design for mobile devices has more often looked at changing the representation of the interface or the data.

The simplistic approach of just presenting the same data on each device does not takes into account, what is known about the performance characteristics of users using data on small devices (Watters *et al.*, 2005). Studies show that screen size does have an effect on performance. A study by Jones *et al.*(1999) examined the effect of screen size on the overall metric performance and they found that the smaller screen size impeded both focused and less directed search task performance using web based Reuter's text data. Line width has been shown to affect performance more than number of lines. Duchnicky & Kolers (1983) showed that width was more important than height for comprehension of text on a screen. Resiel & Shneiderman (1987) showed that smaller screen size result in slower reading time of programming text.

In connection to menu selection or design, studies indicate that navigational issues related to the reduced display area have an affect on performance as well. Accessing data on a smaller display often involves additional scrolling (Watters, Zhang & Duffy, 2005). Kamba, Elson, Harpold, & Stamper (1996) concluded that semi-transparent navigational widgets[30] improved performance on news reading on personal digital assistant (PDA) sized screens. Dillon *et al.*(1999) confirmed that smaller screen results in many more page forwards and backwards interactions when subjects were asked to read and summarize text presented in small windows. Shneiderman (1987) tested completion time of tasks involving selecting hypertext links and found that the number of lines of text given did not significantly affect the time to complete the task.

It is remarkable that in menu-based access does not affect hierarchical menus as much (Swierenga,1990). However the organisation of menu has an effect on performance (Watters, Zhang & Duffy, 2005), Han and Kwahk(1994) demonstrated that searching through menus on single line displays is much slower than on conventional displays. All these discussions demonstrate that handhelds have considerably small screen size and these small screen sizes do have an impact on user's performance. As previously discussed in this chapter, one can not ruled out the demand of restructuring menu interfaces and need to rethink on new interface design possibilities for small

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[30] a generic term for the part of a graphical user interface that allows the user to interface with the application and operating system. Widgets display information and invite the user to act in a number of ways. Typical widgets include buttons, dialog boxes, pop-up windows, pull-down menus, icons, scroll bars, resizable window edges, progress indicators, selection boxes, windows, tear-off menus, menu bars, toggle switches and forms. The term also refers to the program that is written in order to make the graphic widget in the Graphical User Interface look and perform in a specified way, depending on what action the user takes while interfacing with the GUI.

screen sized devices.

Today's graphical interactive systems largely depend upon pointing actions, i.e. entering an object and selecting it (Accot & Zhai, 2002). The emergence of computing devices such as the Tablet PC™, large-screen tabletop displays, wall displays, and personal digital assistants have increased the prevalence of direct pen input. This shift has created a need for suitable interaction styles. On screen interaction, objects are primarily GUI (comprising menus, icon etc.). With some exceptions, most applications have chosen to utilize pen-input devices simply as a replacement for mouse input. Although mice and pens (or styli) both provide two degrees of freedom for input, the form factor of each device is unique and should be considered when designing applications. An important distinction is that pen-input devices can be (and typically are) used as direct input devices (the control or hand space is the same as the display space), thus introducing an effect of occlusion by the hand holding the device. Occlusion is not present with indirect input techniques (Hancock & Booth, 2004).

Input techniques are becoming interesting while making decisions on screen available options. However, it is out of the study area, effect on menu placement is rather useful to discuss. In two-dimensional presentation, the direct manipulation paradigm allows rapid but imprecise object placement. To perform useful work in the context of a complex application such as a document editor, direct manipulation often needs to be constrained by techniques such as gridding or snap-dragging (Bier & Stone, 1986). It clearly indicates the problem area of multiple degree-of-freedom input in coarse positioning tasks vs. precise positioning tasks (e.g. in menu position). Users may have difficulty controlling an interface, which requires simultaneous, precise control of an object’s position and orientation (Hinckley *et al.*, 1994). With our hypothesis of non-linear menu placement, we are equally assuming that it could be a better match for input devices and with better selection performance. An overall performance measured in terms of time could illustrate the effect of different menu placement techniques. Let us see the problem associated with linear menu in following section.

3.4 Discussion 3: Is the menu better way to represent in small interfaces?

The common way to access various functions in a PDA is to use a menu feature. The menu is mostly arranged hierarchically so that the number of available items in a single selection list can be kept within reasonable limits, and to guide the user logically through various features in a phone (Helle *et al.*, 2001). This menu hierarchy may become as large as that of a moderately sized desktop application. Myers *et al.* (1999) argued that interfaces on these very large and very small displays cannot typically use the standard desktop model, and people will not necessarily expect these devices to act like "regular" computers. Hence designing menu systems for in PDAs similar to cell phones is made more difficult by several factors:

- Discrete selection actions are usually needed to move from one menu item to any other, because most PDAs lack more direct selection capabilities (e.g., a mice or touch screen),
- PDAs displays are small, allowing only a few menu items to be displayed at a single time,
- There is less standardisation in hardware supporting menu traversal for PDAs than for desktop machines.

If interfaces are developed for the lowest common denominator, independently of specific hardware (which is common practice at the mobile application level), then even cell phones with sophisticated interaction support become less efficient. Lasky *et al.* (1998) compared the 3Com PalmPilot with Windows CE devices often made the point that the windows user interface style created for the desktop does not work well on palm-size devices. Similarly, the standard windows widgets such as pull-down menus are not appropriate on large wall-size displays since, for example, the menus may be literally too high for short users to reach (Pier & Landay, 1992).

We can expect a dramatic increase in the diversity of both the types of computing devices in use, and the task contexts in which they operate. Overall, these factors suggest that PDAs menu interfaces deserve close analysis, and that they may need specialised techniques for their development and evaluation. This in turn implies that we are poised for a major change in user interfaces. The main problem in laying menu items in linear way arises due to confined size of PDAs; let us see what effect does have size of screen on menu selection and users performance.

3.4.1 Problem associated with linear structured menu

Menus are mostly presented in a linear fashion, listing items from the top to bottom of the screen or window. Pull-down menus are a common example of this format. Bitmapped computer displays, however, allow greater freedom in the placement, font, and general presentation of menus (Callahan *et al.*, 1988). Callahan et al. (1988) used the principle of non-linearity while designing pie menu for desktop applications. They came out with an empirical comparison of pie vs. linear menus and found that

> "*In presenting a list of choices to the user, most computer system designers have been limited, largely by the available hardware and software, to a linear format. The items are listed from top to bottom, sometimes with an index number for each to the item. Occasionally, the lists are multi-columned, have multiple items per line, or are even hierarchical (i.e. indented sub-choices), but for the most part lie in a strictly one-dimensional structure. Many of these menus are static on the display screen or activated from mouse. Whereas a pie menu is a format where the items are placed along the circumference of a circle at equal radial distances from the centre. Pie menus gain over traditional linear menus by reducing target seek time, lowering error rates by fixing the distance factor and increasing the target size in Fitts's Law, minimizing the drift distance after target selection, and are, in general, subjectively equivalent to the linear style*"

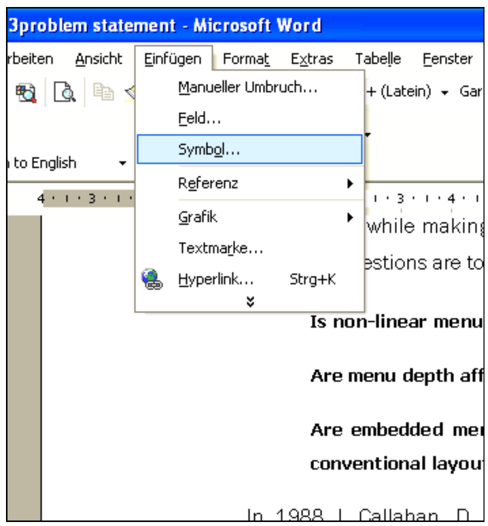

Figure 3-3 A typical linear menu in desktop application

Option or item placed in a menu system has been an important subject matter for researchers in many years but structural arrangements has been simply ignored specially in case of small screen devices. It is generally agreed that the performance of subjects (i.e. time to seek a target) with different placement styles converges with practice (Card *et al.*, 1983; Perlman, 1984). Further Mcdonald *et al.* (1983) revealed that a functional placement of items is superior when the task domain is unambiguous to the user whereas an alphabetic organisation can be useful in uncertain task descriptions. All of these studies have concentrated on the linear display format (Callahan, Hopkins, Weiser & Shneiderman, 1988). Therefore, an empirical study on small screen devices like PDAs make the sense to find out whether alternative menu structures have impact on use pattern.

There are many techniques frequently used for communication between humans and computer systems. They vary widely in their ease of learning and use, and their broad-spectrum applicability. Menu selection is one of the techniques for human- computer interaction. While conducting a study on controlling the Complexity of Menu Networks Brown (1982) suggested that

> *“The solution to this problem of unmanageable complexity is the same for menu as for programs: the disciplined use of a set of well-defined one-in one- out structure”*

In case of desktop computers, most of the computer's have ability to locate and display large quantities of information quickly as a result the human's are able to make fast decisions in the context of a particular problem. A common approach to the design of user interfaces is the menu selection technique. Each menu frame can be considered a node in an information/ action network. The set of nodes and the permissible transitions between them (menu selections) form a directed graph, which, in a system of substantial size, can be large and enormously complex. In contrast to desktop computers, it can be easily understood that mobile device interfaces are even more imperil to this kind of menu complexity.

For the ease of understanding, we put menu complexity in mobile devices and desktop computers side by side. Common use pattern of desktop are often less frequent but for continuous and prolonged period (e.g. in office work) whereas mobile users in contrast uses small screen devices more frequent but for shorter duration (e.g. notes taking). Short duration use of mobile devices makes it even more complex to learn. These rigorous and relevant problems associated with small screen size of display, limitation of using hierarchical items in linear menu needs identification of other form of options representation in PDAs.

Concept of non- linear or spatial arrangement of options attracted previously some of the researchers. Demasco P. (1994) applied “Spatial Contiguity Principle[31]” while

[31] If one accepts the Perceptually Smooth Movement Principle, a second principal naturally follows. In order to achieve smooth movement through the information space, it is necessary that the space be contiguous. A common example of interfaces that violate this principle comes from the area of hypermedia. These systems typically consist of a collection of separate information spaces that at best is linearly contiguous. Connections are more often made through semantic links such as labeled buttons. Given its widespread application and

investigating the application of spatialisation and spatial metaphors to interfaces for augmentative and alternative communication. Here one must take into consideration that in case of hypermedia navigation the phenomenon of users getting lost is well documented (Elm & Woods, 1985). Gren T. (1987) discussed the issue of contiguity in hypermedia and suggested the use of structures such as timelines and maps as a means to support the concept. This fundamentally would provide greater contiguity to the information space. Though many interface designer favour linear menu also in PDAs, this can be simply realised in available PDAs marketed almost all of them have linear menu. With the introduction of graphical user interface, since last few years, PDAs are available with non-linear iconic options available in mobile phone and PDAs both. Some devices offers personalising device menu, in which users have options to rearrange menu items, either in "list view" or in "symbol view". These developments are still confined to the device main menu, and are not addressed to the applications running in devices. This is because there are no standardised norms, principle or rule of determining menu structure in small screen devices. Mostly metaphor used in desktop interfaces, have been imposed in PDAs as well. Therefore, our main research intention is to find the answer of following questions in case of PDA interfaces.

Is non-linear menu structure is better than linear structure?

Is menu depth affects user performances in linear menu structure?

Structure of menu means the placement of menu on display here i.e. how the menus (set of options) are arranged, are they linear or non-linear (more on linearity and non-linearity is discussed in next chapter 4). As in case of sequential, hierarchical or simultaneous linear menu, set of options are often distributed in various level (depth) so that relevant options can be categorised and arranged, menu depth plays an important role in user's performance. In case of non-linear menu, depth of one options to other options are kept always constant, therefore leaving it apart from research problem.

3.5 Summary

Every household has at least a range of small screen devices such as CD players, video recorder, television, calculators, mobile phones, clock, radio etc. each

acceptance, it would be difficult to dismiss the hypermedia model from the perspective of spatial contiguity. However, one of the most commonly discussed problems within hypermedia research is that of navigation.

of these devices are equipped with or made of small interface. The problems related to small interfaces are worth of mentioning as limitations set by small dimensions and limited way of interacting makes small interfaces more problematic to design.

The problem is so similar with those in the PC realm that many of the 'golden rules' of interaction design apply to small interfaces as well but not all. However, complexity or difficulty in using linear menus does provide additional information to the developer and designer. It is necessary to deal small interfaces separately with their distinctive mode of operation because small screen is associated with different problem. One cannot conclude that small interfaces are always symmetric to the desktops or somewhat large display interfaces. Henceforth, it is necessary to research separately the small interfaces as they have varied dimension of analysis area.

The problem related to small interfaces seems not to be momentary. PDAs displays are small, allowing only a few menu items to be displayed at a time. Windows user interface style cannot work well on palm-size devices. This in turn implies that we are poised for a major change in user interfaces and suggest that PDAs menu interfaces deserve close analysis, and that they may need specialized techniques for their development and evaluation.

In case of PDAs, linear menu hierarchy can be as large as that of a moderately sized desktop application. Hence designing menu systems for in PDAs similar to cell phones is made more difficult.

In handhelds, size of display plays a predominant role while information processing and retrieval. Many interactive applications have complex interfaces that consume considerable screen space. Interactive applications are menu enriched to enable users with more degree of freedom to use the features. Nevertheless, considerable amount of research has been carried out to improve linearly organised menu system for large displays it becomes more tedious to deal with in case of small screen sized devices. Therefore, menu design for small screen needs more attention and cleverer solutions to get optimum result and user’s satisfaction. The simplistic approach of just presenting the same data on each device does not take into account what is known about the performance characteristics of users using data on small devices. Studies show that screen size does have an effect on performance. One study examined the effect of screen size on the overall metric performance and they found that the smaller screen size impeded low task performance.

Accessing data on a smaller display often involves additional scrolling. Smaller screen results in many more page forwards and backwards interactions when subjects were asked to read and summarise text presented in small windows. All theses discussion demonstrates that handhelds have considerably small screen size and this small screen size does have an impact on user's performance. As previously discussed in this chapter, one can not rule out the demand of restructuring menu interfaces and need to rethink on interface design possibilities for small screen sized devices.

The quality of the user interface is an important dimension of software quality that significantly affects user satisfaction, productivity and effectiveness. A good user interface is therefore, must be compatible with the user's mental model and expectations, implying a good fit between the user model and the design model. Options or items placed in a menu system have been an important subject matter for researchers in many years but structural arrangements have been ignored specially in case of small screen devices. Users may have difficulty controlling an interface with linearly arranged menu, which requires simultaneous, precise control of an object's position and orientation.

Non- linear structure of menu organisation uses partially the benefit of spatial (non-linear) hypertext visualization principal. Cellular phones are a widespread example of a menu-driven technical device whose, usage still imposes difficulties on many users. The variables referred to the complexity of the menu are depth/breadth of the menu tree and their structural arrangement. Therefore, we identified research problem confined to the complexity of interface in case of PDAs are linear arrangement and depth/ level of available options. Finally, research problem is identified to get the answer, if depth of available options in linear menu affects the performance and therefore, non-linear menu proves better in small sized display devices (PDA).

Theoretical groundwork for research is explained in the following chapter.

Chapter 4

Theory

*"…..Terror. You have to confront the documentation. You have to learn a whole new language. Did you ever use the word '**interface**' before you started using a computer? "*

-- Advertising executive Arthur Einstein

***Interface**: . . . a: the place at which independent systems meet and act upon or communicate with each other b: the means by which interaction or communication is effected at an interface*

-- Webster's Seventh New Collegiate Dictionary

4.1 Introduction

"At a certain stage in the development of every science a degree of vagueness is what best consists with fertility," wrote William James in 1890, and the field of human-computer interaction has not yet advanced beyond that stage. The goal is to show that the way we use these words conceals important changes in our field. The term "user interface" came into use when our field was like chalk and cheese than it is now. At that time, it served a valuable purpose. Most of us now feel quite comfortable with it, although we may not use it entirely consistently. Henceforth, to the next I will discuss the possibilities for confusion and misdirection in our use of this and related terms in the changing environment of computer design and use. Continuing the current usage may reinforce and bind us to an obsolete perspective. The power of words is not total, but they may indirectly inhibit the adoption of new areas of research and approaches to development. Current chapter explores the theory associated to user, interface, and menus. It will also be discussed the implementation of theory and definitions which are used to carry out the research study.

The term "user interface[32]" started its usage originally in the engineering

[32] User interface - (computer science) a program that controls a display for the user (usually on a computer monitor) and that allows the user to interact with the system.

environment. Virtually all computer users had been engineers and programmers, but a new kind of user was emerging i.e. the non-programming user. These users repeatedly reacted more negatively to difficulties in dealing with the machine. Simpler forms of interaction were needed, thus a new interface attention resulted into 'the user interface'.

In the next paragraphs, the term 'user' is discussed. Then the term 'interface' is explored, with due fact that a user's interface to a computer does not match or complement a computer's interface to a user. 'User interface' is often used to describe a computer's interface to the user, rather than a user's interface to the computer.

4.2 Who are the users?

Humans are tool users. We use tools to extend our grasp, to see beyond the horizons and beneath the soil, to build things and to tear them down. Identifying the users may seem like a simple question, but in fact, there are many interpretations of use". The most obvious definition is those people who interact directly with the product to achieve a task. Most people will agree with this definition; however, others can also be considered as users. Eason (1988) identified three categories of users: primary, secondary and tertiary. Primary users are those likely to be frequent hands-on users of the system, secondary users are occasional users or those who use the system through an intermediary; and tertiary users are those affected by the introduction of the system.

4.2.1 Definition of user

The most applied and accepted user classification defines "*novice, casual and expert users*" (Nielsen, 1993). We define a novice user as a person who either never used a PDA handset or has minor experience with it. For example, a novice user may have made or received a phone call with a mobile handset. A casual mobile handset user may own a mobile handset using occasionally some basic functions of the PDA, for example the built-in phonebook. His lifestyle is not based on the use of a PDA handset. An expert user has his PDA handset always with him and he uses different functions fluently and often. An expert user has owned some other PDA handsets earlier. However According to Tech encyclopaedia on IT terms user is defined in general as:

> *"Any individual who interacts with the computer at an application level. Programmers, operators and other technical personnel are not considered users when working in a*

professional capacity on the computer[33] *".*

The above definition demarcates user in two types viz. novice and other who is expert. One is considered as 'user' when he is really a user of application but not in case where he is using it in his professional life. This definition appears to be justified as because desktop computers are deeply penetrated in our professional life. Today every workplace is well equipped with this prime IT tool. Anyway, we leave this definition in our case, however it provides a basic to understand mobile or handheld user.

In contrast, in studies of work or professional life, the mobile user or mobile consumer is characterised as an individual who uses mobile telecommunications in specific organisational settings and relationships. As we shall see, this is both complemented and challenged by industry conceptions of the mobile consumer where consumers are sometimes conceived not as individual users but as organisations themselves (Green *et al.*, 2001; Brown *et al.*, 2001). In the present context, focus is on the diffusion of mobile telecommunications into the personal lives of users. As mobile phones have diffused into private and leisure spheres, conceptions of the mobile user have changed. Like the case of the fixed line phone (Fischer, 1988), social uses have increased as individuals fitting the technology and assimilating it into their everyday lives for private and leisure purposes. Diffusion into the domestic sphere in particular underlines the gendered uses of mobile communications and computing technologies (Frissen V, 1995); (see also Silverstone R., 1992;1996). Qualitative studies have indicated that women often bought mobile phones for safety, for example, but soon begin to use them for tasks associated with their gendered roles in the private sphere – for care giving, or for communicating with their children and other members of their extended families (Frissen, 1995; Rakow, 1992). Though, according to Ling (1999), this is a response to changing patterns of everyday life where *". . . familial solidarity and continuity are an ongoing problem in the face of mobility, divorce, dual careers and the stress of daily life".*

Fischer (1988) and Rakow (1988) found that many users have acquired their mobile phones through work roles, although acquisition through these means has not prevented its usage as a community and social technology in contrast to its expected uses.

[33] Retrieved from http://www.techweb.com/encyclopedia/defineterm on 14.02.2005

According to Frissen (1995), basic ownership and usage statistics have indicated that diffusion and ownership of mobile phones has generally followed a similar pattern to that of fixed-line phones.

In fact, the mobile telephone was initially believed by its manufacturers to be primarily a business tool – in other words for business users. Green, Harper, Murtagh & Cooper (2001) contradicted the statement and emphasised the role of industry organisations in promoting the technology, for example, one aspect of telecommunication markets that affects patterns of diffusion and consumption. Telecommunications users are characterised not only through demographic categories, but also through their relationship to the industries and institutions that comprise telecommunication markets. The relationship is described as one where industry organisations structure a market wherein individuals, in the context of the social groups and organisations of which they are a part, both consume in intended ways but also develop their own uses (Green, Harper, Murtagh & Cooper, 2001). However, the fact is the "user" is an individual who appropriates telecommunication technologies in ways that fit with their membership of social groups, life stages and everyday activities of sociability.

One of the prime objectives to understand and define user of handheld device is to assess the relevancy of MTO (as described in chapter 1). In our above discussion of work or professional life we accept that "*the handheld consumer as an individual who uses mobile telecommunications in specific organisational settings and relationships*". It signifies clearly that, consumers are sometimes conceived not as individual users but as organisation themselves. Therefore, person is not a user without a task or a tool to operate, thus the idea of a function is involved. In addition, without the user the tool is only a combination of materials without any purpose. A PDA alone is just an expensive combination of the metal and plastic, but when utilised, it becomes a tool for various purposes. Theoretically, with this conception of technology -use and users-technology, there exists a possibility that particular technique could be better-utilised in particular organisational setting. Referred to our research problem discussion [3.2, chapter 3] probability of proving an alternative menu structure while using for a specific organisational task, is not avoidable.

We accept two categories of users to apply in our research i.e. users who use

PDA or mobile phone in their daily life and the users who may use these devices to cater their organisational need. Users thus, become conceptualised ***as individuals who utilise technology strategically, for a number of different – but integrated – professional and/or personal purposes, in a number of different social environments and relationships***. Thus, here we clearly distinguish users in terms of their professional need as well. One, who uses a technology (e.g. PDA) for their personal use or leisure or entertainment, other who uses a technique (e.g. PDA again) in their professional life at work place to complete the task given by his organisation. This division would provide us a basis, while selecting subjects in our experiment design.

4.3 Evolution of interface

As we are investigating complexity of interface, it needs to be understood, what are these interfaces? Interface is the term frequently used in many other contexts. It has different meanings in accordance with the context used (e.g. man –machine interface, human-computer interface etc.). For the ease of understanding in our context of PDA interface let me discuss and define the interface in following paragraphs.

4.3.1 Definition of interface

In general, the connection and interaction between hardware, software and the user is referred to interface. Hardware interfaces are the plugs, sockets, wires and the electrical pulses travelling through them in a particular pattern. Also included are electrical timing considerations. Examples are USB[34] transmission, the Ethernet[35] and Token Ring[36] network topologies, IDE[37], ESDI[38], SCSI[39], ISA[40], and EISA[41] interfaces. Software, or programming, interfaces are the languages; codes and

[34] Universal Serial Bus: can connect peripherals such as mice, keyboards, scanners, digital cameras, printers, hard drives, and networking components.
[35] A type of networking technology for local area networks; originally developed by Xerox Corporation; coaxial cable carries radio frequency signals between computers at a rate of 10 megabits per second
[36] A computer local area network arbitration scheme in which conflicts in the transmission of messages are avoided by the granting of "tokens" which give permission to send.
[37] Integrated Drive Electronics
[38] Enhanced Small Device Interface: Hardware standard for connecting disk and tape drives to computers.
[39] Small Computer System Interface: An interface standard for a personal computer that connects up to seven peripheral devices.
[40] Integrated Systems Architecture
[41] Extended Industry-Standard Architecture

messages programs use to communicate with each other and to the hardware. Examples are the applications that run under the Mac[42], DOS[43] and Windows[44] operating systems as well as the SMTP[45] e-mail and LU 6.2[46] communications protocols.

User interfaces are the keyboards, mice, commands and menus used for communication between user and the computer. Examples are the command lines in DOS and UNIX[47], and the Mac, Windows and Motif[48] graphical interfaces. Interfacing is a major part of what engineers, programmers and consultants do. Users "talk to" the software. The software "talks to" the hardware and other software. Hardware "talks to" other hardware. It has to be designed, developed, tested and redesigned; and with each incarnation, a new specification is born that may become yet one more de facto or regulated standard.

4.3.2 Format & Function of interface

Every interface implies a structure. The data passed from one device or program to another has a precise format (header, body, trailer, etc.). Every interface implies a function. At the hardware level, electronic signals activate functions; data are read, written, transmitted, received, analysed for error, etc. At the software level, instructions activate the hardware (access methods, data link protocols, etc.). At higher levels, the data transferred or transmitted may it request functions to be performed (client/server, program to program, etc.). Similarly, interface of a PDA have also a format and function. Precisely in our case, a user interface is activated on the display area of the PDA. This also has a structure (or format) in which, header may shows basic information about function of PDA and trailer some inbuilt functionality of the device (e.g. time). Apart from that, some area is available for

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[42] The Macintosh, now correctly called the Mac (since its introduction, Apple has officially changed the name of the computer to Mac), is a family of personal computers manufactured by Apple Computer, based in Cupertino, California, USA.
[43] Commonly refers to the disk operating system originally developed by Microsoft, Inc. for use on personal computers. This operating system also refers to that operating system which is used on IBM-compatible personal computers.
[44] Microsoft Windows is a range of operating environments for personal computers. The range was first introduced by Microsoft in 1985 and eventually came to dominate the world personal computer market. All recent versions of Windows also function as a fully-fledged operating system.
[45] Simple Mail Transfer Protocol
[46] Logical Unit 6.2: type of communication protocol
[47] Is a portable computer operating system originally developed by AT&T Bell Labs
[48] Is a graphical widget toolkit for building graphical user interfaces under the X Window System on UNIX

body, i.e. the main area of interest in our case, where an application may run on the device. This part of interface has function to display the application programme with its unique menu features. In fact, all this is achieved by programming language command running behind the application.

4.3.3 Language & Programming

An interface is activated by programming language commands. The complexity of the functions and the design of the language determine how difficult it is to program. It is not covered in our research to asses how difficult or easy is the language to programme in linear or non-linear menu of particular interface. Moreover, whether linear or non-linear menu of a user interface, they are activated by writing commands in suitable language or using application-programming interface (API) bundled with software language.

4.3.4 User Interface, Protocol, API and ABI[49]

The design of the interaction between the user and the computer is called a "user interface." The rules, formats, and functions between components in a communications system or network are called a "protocol." The language and message format between routines within a program or between software components is called an "API”. The specification for an operating system working in a specific machine environment has been known as an "ABI," but this term is not widely used.

All the above interactions are interfaces. Regardless of what they are called, they all create rules that must be precisely followed in a digital world. Interface relationship in a typical desktop computing system is illustrated in figure 4.1. If not much alike in case of small screen devices, the fundamental working can be identifying with those with desktop. This is described here only for the purpose to understand how the work and function. More on “user interface” is discussed in the following paragraphs.

[49] Application Binary interface

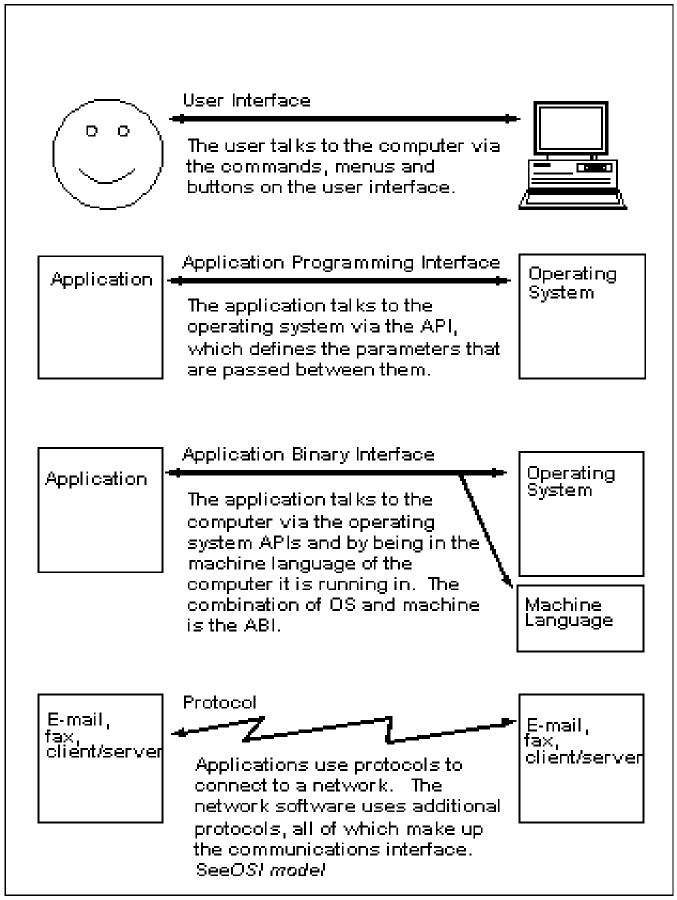

Figure 4-1 Interface relationship in desktop system

Paradoxically, 'user interface' is a technology-centred term. The interface is between users and computers. We have asymmetrically abridged "user-computer interface', retaining the name of only one of the two actors. '*The computer is assumed'* and *"the user must be specified"*. There is a good reason for this: in the engineering environment, a computer's architecture includes many internal 'interfaces'. The interface to the 'user' was one of many interfaces that had to be discussed; so labelling it 'the user interface' was an obvious and non-controversial choice.

There was no need to call it the 'user-computer' interfaces, because in the engineering environment, the computer could indeed be safely assumed! However, 'user' was a convenient identifier among engineers; its use has spread - beyond the engineering environment, creating confusion in several ways.

The word user interface signified the segment of the software program that handled dialogue with users; we generally do identify 'the user interface' with the software that controls I/O[50] devices and processes. Consider the two faces to the user-computer interface. Is a user's

[50] Input/output

interface to a computer the mirror image of the computer's interface to the user? It may seem that it should be, but on reflection, it is not, unless one defines "interface" extremely narrowly. The user's interface to the computer may centre on the software-controlled dialogue, but it also includes any documentation and training that are part of using the computer.

We use the term interface of PDA that has a ***format or structure (body, header and trailer) displayed on the screen. It has function to provide options or commands for the user to perform desired actions to run an application***. In our study, we are confined to the 'body' part of interface where menus are displayed. Since menus represent here implicitly a communicating interface with user, it can also be interchangeably referred as user interface.

4.3.5 User interfaces in small screen displays

User interface became a major issue in most software development only when people other than programmers or operators began to have direct, hand-on access to computers (Constantine & Lockwood, 1999). This is truly applied in case of small screen handheld devices, where user in real sense mainly uses the system in a way that they are neither programmer nor operator. These devices are used in daily life and partially to work with routine problem solving tasks such as text editing, spreadsheet applications etc. the modern concept of user interfaces in computing dates from the arrival of terminal connected directly or indirectly with computers. As more people could interact with computers directly, the interface between these users and the computer with its programs became a subject of increasing importance for the designers and developers of programs (Constantine & Lockwood, 1999).

From design point of view, a PDA handset is, at first, an interactive system. (ISO 13407, 1999) defines an interactive system: "*a combination of hardware and software components that receive input from and communicate output to a human user in order to support his or her performance or a task"*. From user point of view, a PDA handset is an information appliance: "*an information appliance is designed to perform a specific activity, such as music, photography, or writing. A distinguishing feature of information appliance is the ability to share information*" (Bergman, 2000). Finally, a PDA handset is a personal communication system enabling communication between humans and between human and another interactive system.

A small screen user interface is an entity that is built from several factors. These technical factors and details form the familiarity, look and feel, and finally usability of a mobile handset. We can divide these factors to the two different categories: user interface and external interface. (See also chapter 2)

The user interface category includes input and output devices and techniques, industrial and mechanical design and application (software) factors. Input tool of a PDA handset is typically an inbuilt keypad and sometimes voice input is possible for some models of available PDAs operation. Voice is the main information and communication channel. Mobile handset interfaces need special control tools, such as navigation and call management keys. Output is given as audio (speaker) and as display activity (icons, indicators). The industrial and mechanical design define, for example, whether the phone is pocketable, user can use it with one hand, if the SIM card and battery handling are easy and if the buttons are easy to press (Ketola, 2000).

To make it clear let us acquainted with how these interface are developed. As in many cases, the user interface is created based on an analysis. From the task and user data, an initial design is created which is then subjected to many incremental development cycles. Effective use of contextual data about the users and their tasks is crucial for the design of usable and useful systems. It gives designers the necessary knowledge to understand how users can be supported in their work. Both in the creation and evaluation activities, this knowledge play an important role. In addition, the designer's expertise and explicit design knowledge such as guidelines and patterns are used to create the user interface. Designing user interface means that many aspects such as functionality, dialog structure and presentational aspects need to be considered. Hence, the user interface is more that just some windows.

As we are specifically concerned to menu structure, instead of analysing the whole span of user interface, we consider user interface more or less as a surface. For experiment, we have developed two different menu structures that have same objectivity (i.e. they can perform the same task successfully but with varied capacity). These menus are in simulated environment and realised by developing prototype for each.

4.4 Menu in small interface

Menus were originally designed to exploit the fact that humans are better at recognising commands from a list rather than recalling a particular command name from memory.

When first introduced, menus provided an easy-to-use alternative to the more prevalent command line systems. Certainly, given the limited keyboard size in case of cellular handsets, menus represent a significant advantage over any command line system. The constraints in screen size and form factor also favour menu-based dialog over a mouse based graphical user interface. Consequently, the reasons for choosing a menu-based interaction would seem sound. Therefore, all handsets currently support some form of hierarchical menu to access the functionality of the device. None is well, however.

Techniques, like menus, translated directly from desktop to hand-held, without fully considering the consequences, can cause interaction problems. The reduced size of embedded computer systems means that interacting with handset menus is more burdensome as compared to their desktop counterparts. Han & Kwahk (1994) reported that users being up to three times slower when using menus on a small screen. In the case of PDAs, this has caused frustration and rigorous complaint came from many users.

Definition of Menu

An on-screen list of available functions, or operations, that can be performed currently. Depending on the type of menu, selection is accomplished

1. By highlighting the menu option with a mouse and releasing the mouse,
2. By pointing to the option name with the mouse and clicking it,
3. By highlighting the option with the cursor keys and pressing enter,
4. By pressing the first letter of the option name or some designated letter within the name.

Modern menu is, quintessentially, a metaphor. The original knowledge base is that of ordering items in a restaurant. Webster's new universal dictionary of the English language (1976) gives the following definition of menu:

> *Menu n. [Fr., small, detailed, from L. minutes, pp. of minuere, to lessen, from minor, less] 1. a detailed list of foods served at a meal; bill of fare. 2. The food served.*

Here the menu represents a finite set of items available at the establishment. The customer then makes a selection and informs the server. The order is then prepared and served to the customer. In a similar way, the computer or PDA display a detailed list of options available using the program. That means current applications of computer or PDA menu bear more or less the same functionality principal. In the field of HCI, several studies have been conducted to see the similarity and dissimilarity between restaurant and computer menus.

We will follow simple definition of menu that, ***menu provides users a set of choice that can be a list of options related to commands by which the user can perform actions related to the task in hand and therefore are based on task structure*** (and the information required to perform the task). However, in PDA like devices menu provides interactive approach of control by listing available options we believe that menus can convey much information to the user and aid novice users as well as more experienced users.

4.5 Structure and organisation of menu

The common way to access various functions in a PDA phone is to use a menu feature. The menu is arranged hierarchically so that the number of available items in a single selection list can be kept within reasonable limits, and to guide the user logically through various features in the phone. While navigating, the menu of a typical modern mobile phone gives feedback in the form of texts and graphics (icons). Sounds are not used except for keypad tones, which are the same regardless of the context or the key pressed. Telephone-based interfaces such as PDA phone menus offer by nature a very basic form of interaction. Because the size of the screen prevents the menus to offer as graphical feedback as desktop menus do, and because the menus involved can feature several hundred nodes, users can easily lose track of their actions while navigating.

Men never ask for directions and women cannot read maps,

-at least according to popular myth.

However, convergence of smart phones and global positioning systems (GPS) could consign those stereotypes to the dustbin.

The mobile is becoming a wireless navigation tool, with spoken instructions to guide user from door-to-door through every twist and turn of your route wrote Brannan

P. (2004) at BBC[51] news interactive, in his article.

Menu structure refers to the branching capabilities of the menu. Menu structure determines the scope to which the current selection affects successive options. How a menu structure serves a purpose in determining the proper sequence of transactions between the user and the PDA will be a central idea while comparing linear and non-linear structures of menu. Users may often wish to or need to jump to another activity. In the field of HCI study, menu structures previously have been criticised because they have not allowed the users to escape from a particular menu path in order to complete some other task and then return to the previous point in the menu. More and more systems are beginning to allow the user to execute task according to the user's plan of action rather than a forced path of options. Non-linear structure of menu are the next generation innovation as day by day graphical user interface is strengthening and the technology is developing it self.

According to Norman (1991), the physical format of the menu may either support the user or slow down performance, Depending upon how well it conveys information. The essential requirement for an effective menu is that layout should highlight the options and organise them in a meaningful way to help in performing the task, it should help to set the context of where the user is in the flow of control through the menu structure, and it should aid the user in the decision process.

Menu structures represent the flow of control given to the user in a task. The formal structure of a menu system can be defined using concept of set theory, abstract algebra, or state- action graph. However, from the perspective of the user and the logic in which they control program flow in a PDA can be broadly categorised in linear and non-linear structure. Linear menu may be single menu, sequential linear, simultaneous, hierarchical, cyclical/ non-cyclical and event menu. Non-linear structure is the recent trends of organising the menu and can use all the advantages of linear menu structure, simultaneously presents easy look and feel to the users.

4.5.1 Structure principle of menu design

The structure principle is concerned with the overall user interface architecture and directly reflects the notion of user interface design as a dialogue between

[51] British Broadcasting Corporation, London

developer and user. According to structure principle "*the user interface must be organised purposefully, in meaningful and useful ways based on clear, consistent models that are apparent and recognisable to users, putting related things together and separating unrelated things, differentiating dissimilar things and making similar things resemble one another"* (Constantine & Lockwood, 1999). Concept of non-linear menu is primarily based on the structure principle. If we look on the theoretical basis of non-linear systems it becomes clearer how grouping and branching of menu options cannot be realised without structure principle. Non-linear interface is deliberately organised in a way that reflect the structure of task/content being represented and the way in which user think about the task/content available on screen.

Analogous example of a non-linear menu would be a structure like **periodic table**[52] of chemical elements. Alike periodic table where each elements are arranged in a tabular form in a non-linear way but with a definite relationship among each other and following a well defined systematic approach; a non-linear menu can be structured putting related things together, separating unrelated options, differentiating dissimilar items and making similar choices resemble one another. Promising feature of a periodic table is, though the elements are distributed in a non-linear way, each element has fixed place in the table according to the property (atomic no.) of that element and cannot be replaced by other element. Similarly, menu options can be grouped and sub grouped depending upon the properties and characteristics of each item to find a certain place in menu use pattern. This kind of arrangement gives benefit to ease in structuring and availability of desired action as and when needed.

Figure 4-2 Periodic table shown in a Palm Pilot[53]

52 Invented in 1864 by Mendeleev: Arrangement of chemical elements in ascending order of atomic number into periods, each ending with an inert gas, so that all elements fall into groups and subgroups with similar chemical properties in accordance with their electronic structure.

53 Retrieved from http://sourceforge.net/projects/mpt/ for open source software development project on 27.08.2004

Principle of recurrence in regular cycle (periodic) is another significant feature, which will be adopted while designing non-linear menu for PDAs in my current research thesis. The vital issue is not whether there is a metaphor of Mendeleev's periodic table incorporated into the user interface but whether the interface is then well organised and suited to the specific application area.

4.5.2 Menu arrangement:

Menus may be designed as drop-down, pop-up, or single-dialog menus. It may seem obvious how to design a menu, but if we want to make the application easy to use and provide user satisfaction, some important points must be taken into account. For example, for pull –down and pop-up menus, the most commonly used functions are at the top, to prevent long scan and scrolls. The principle of grouping can be used to good effect in menu design. For example, the menu can be divided into collections of items that are related, with each collection being separated from each other's. (See figure 4.3) Menu names need to be short, clear, and unambiguous. We need to consider logical groupings. We will discuss more on logical groupings and arrangement of menu in non-linear set of arrangement.

Figure 4-3 PDA showing possible linear set of grouped menu

5.2	Grouping options in a menu Menu options should be grouped within a menu to reflect user expectations and facilitate option search.	
5.2.1	Logical groups If the menu option contains a large number of option (eight or more) and these options can be logically grouped, options should be grouped by function or into other logical categories, which are meaningful to users. EXAMPLE: grouping the commands in a word-processing system into such categories as customize, compose, edit, print.	
5.2.2	Arbitrary groups If 8 or more options are arranged arbitrarily in a menu panel, they should be arranged into equally distributed groups utilizing the following equation: $g = \sqrt{n}$ Where G is the number of groups N is the number of options on the panel EXAMPLE: Given 19 options in a menu panel, arrange tem into 4 groups of about 5 options each.	

Figure 4-4 An excerpt from ISO 9241 concerning how to group items in menu

Several studies have investigated the effects of menu organisations on user performance. Somberg (1987) compared four menu organisations: alphabetic, probability of selection, random, and positional constant. However, it is important to remember that for the alphabetic, probability, and random organisations, menu items changed positions between each selection making it impossible to learn the location of an item. Initially, alphabetic or probability ordering were fastest, but after practice, menus that maintained a constant position for each item proved fastest. Random organisations were the slowest throughout the study. These results indicate that keeping words in fixed locations is better than allowing the words to move within a menu. However, it does not provide a comparison between various methods of organising items in a positional constant menu. Card (1982) compared positional constant alphabetical, categorical, and random organisations. Alphabetically ordered menus were the fastest and randomly ordered menus were the slowest. These results indicate that in addition to keeping menu items in fixed locations, a meaningful organisation should also be used. While there is no simple answer to the question of which organisation to use, it is clear that providing users with a stable menu that uses a known organisation results in significant benefits.

Another alternative is to organise dynamically the menu that is based on the current frequency of selection. This could lead to a menu that changes automatically after users make selections, or to a system that is under user control and only changes when the user decides that a change would be beneficial. Mitchel & Shneiderman (1989) compared static menus and menus that were automatically reorganised based on the users' current pattern of selections and found that users preferred static menus. Additionally, when comparing the first exposure to the system, users were faster and made fewer errors with static menus. After practice, there was no difference in performance, but users still preferred static menus. Greenberg & Witten (1985) investigated the benefits of organising menus based on a prior set of frequencies and updating the menu to reflect recent usage as users make selections. The results suggest that putting items in order by frequency of use may prove useful. These two studies indicate that automatically updating menus to reflect current usage patterns may be useful, but can also lead to problems.

Other attempts at speeding up menu selection have used non-linear menus. Callahan, Hopkins, Weiser & Shneiderman (1988) investigated the benefits of circular (pie) menus which make the distance to each item equal, while Walker & Smelcer (1990) explored the benefits of making menu items larger, the farther down they were in a menu. Both of these research efforts focused on making the movement to a menu item easier, and both demonstrated that this can save users time. In the following section, we will see how linearity and non-linearity works with menu.

Linearity and non-linearity can be better understood by dating back to the start of computer assisted instructional programming. The origin of Computer assisted instructions can be credited to the work done by Skinner (1958) and Crowder (1962). These two psychologists are credited with the concepts of linear and non-linear programming leading to programmed instruction and scrambled texts[54], which were limited in scope and application. However since the advent of digital computer, there has been an explosion in the number, scope, and diversity of instructional systems and languages (see Bitzer & Skapadas, 1969; Suppes, 1966 & Zinn, 1969). A study of these programs would show that there are three factors accounting for differences among them, namely the level of interaction, the means by which the instructional content presented, and the decision algorithm by which subsequent instructional steps are selected. However, the level of interaction is constrained by software and hardware factors.

[54] Text Thrown together in a disorderly fashion

In particular menu presented in any system as instructional content of selecting options make it very relevant to have the control on sequencing. However, there are two methods for using the instructional content – selective and generative method. In the selective method, system actions and reactions are pre-programmed so that the computer serves essentially as an information storage and retrieval medium without actively participating in the instructional process. As opposed to the passive role played by the computer in the selective method, the generative approach attempts to develop adaptive programs with algorithms for making decisions of a dynamic nature throughout the instructional process.

During the course of control on sequencing, options could be branched either linear or non-linear (See figure 4-5).

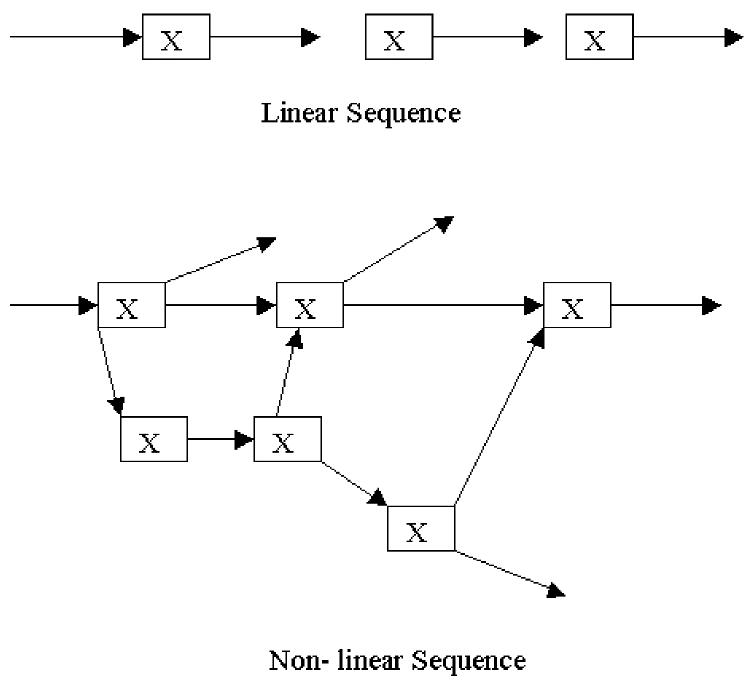

Figure 4-5 Branching pattern and Sequence

In linear branching, there exists only one subsequent step to any given step (Skinnerian logic[55]) while the non-linear branching selects the subsequent step from an array of alternatives based on a set of tested conditions. These branching conditions can be classified as either intrinsic (restricted to the immediate environment of the instructional step) or extrinsic (derived from variables beyond the

[55] Coined after the name of behavioural psychologist B. F. Skinner

immediate environment). To be familiar with non-linearity, we have to understand linearity first.

One of the defining peculiarities of this subtitle is that the term 'linear', and the derived term 'linearity', occur in general with two very different meanings. These two meanings almost never occur together in human activity, because of the fact that usually separates the artistic and the mathematical worlds.

For the graphic artist, 'linear' means, 'having the properties of a line'. The artistic property of a line is that it has a pull in some direction, and also in the opposite direction, but not in any intermediate direction. The better an artist is, the more difficulty he/she would have in providing an objective definition of linearity.

To the mathematician, 'linear' means that if we multiply what we put into an expression by some amount, what we get out is multiplied by the same amount.

To the computer programmer, 'linear' means, 'free of surprises'. In contrast, chaos Theory [56] is the study of non-linear processes. Precisely speaking we can define linearity as:

"The property of having one dimension" [WordNet 1.7.1, 2001, Princeton University]

[56] Established in the 1960s, chaos theory deals with dynamical systems that, while in principle deterministic, have a high sensitivity to initial conditions, because their governing equations are non-linear. Examples for such systems are the atmosphere, plate tectonics, economies, and population growth. The theory has roots back to around 1950 when it first became evident for some scientists that linear theory, the prevailing system theory at that time, simply could not explain the observed behaviour of certain experiments like that of the logistic map. The main catalyst for the development of chaos theory was the electronic computer. Much of the mathematics of chaos theory involves the repeated iteration of simple mathematical formulas, which would be impractical to do by hand. Moore's law and the availability of cheaper computers have greatly increased the extent of chaos theory. As of 2003, chaos theory continues to be a very active area of research. An early pioneer of the theory was Edward Lorenz whose interest in chaos came about accidentally through his work on weather prediction in 1961. Lorenz was using a basic computer to run his simulation of the weather. He wanted to see a sequence of data again and to save time he started the simulation in the middle of its course. He was able to do this by entering a printout of the data corresponding to conditions in the middle of his simulation, which he had calculated last time. To his surprise the weather that the machine began to predict was completely different to the weather calculated before. Lorenz tracked this down to only bothering to enter 3-digit numbers in to the simulation, whereas the computer had last time worked with 5-digit numbers. This difference is tiny and the consensus at the time would have been that it should have had practically no effect. However Lorenz had discovered that small changes in initial conditions produced large changes in the long-term outcome. The importance of chaos theory can be illustrated by the following observations:
In popular terms, a linear system is exactly equal to the sum of its parts, whereas a non-linear system can be more than the sum of its parts. This mean that in order to study and understand the behaviour of a non-linear system one need in principle to study the **system as a whole** and not just its parts in isolation.
It has been said that if the universe is an elephant, then linear theory can only be used to describe the last molecule in the tail of the elephant and chaos theory must be used to understand the rest. Or, in other words, almost all interesting real-world systems are described by non-linear systems.

In our study, linear menu are subjected to the path of menu in a single direction (uni-directional).

Non- linear layout expresses a spatial[57] relationship i.e. hyperlink relationship to a topological space, composite structure to a graph/set, and search results (from information retrieval) to a vector space. The content or attributes of node may be used to embellish the space, or contents may themselves display some spatially meaningful structure. Thus, spatiality or non-linearity must be understood as a characteristic that refers to a location (which may be a specific location on any surface or relative to an arbitrary point on that surface).

We are defining non-linear menu structure ***where every node of menu has more than one direction to follow (multi-directional). In this type of structure user has more than one degree of freedom to move. Every time the distance of available options is same to the start point of action***.

4.5.2.1 Linear menu

Linear menu have only one path. The path of linear menu system may extend from 2 to n levels and incorporates an iteration of single menu frames. Simple example of linear menu is widely used in set top box to transmit programs in television is illustrated in figure 4-6.

Figure 4-6 Typical linear menu in set top box

Settings menu is organised in say 'n' no. of frames and user paged to the desired task in a linear way. If the user makes any mistake, she is forced to exit the path

[57] Term used interchangeably for non linearity in particular while speaking about user interface

by pressing exit button in remote.

Similarly in PDA or any other handheld device all the menus that are linear-hierarchical grouped, if one makes false decision while selecting the option is forced to leave the started path and consequently forced to start the same from beginning again. Working principle of linearly organised menu can be better understood while studying control flow, which is illustrated in figure 4-7.

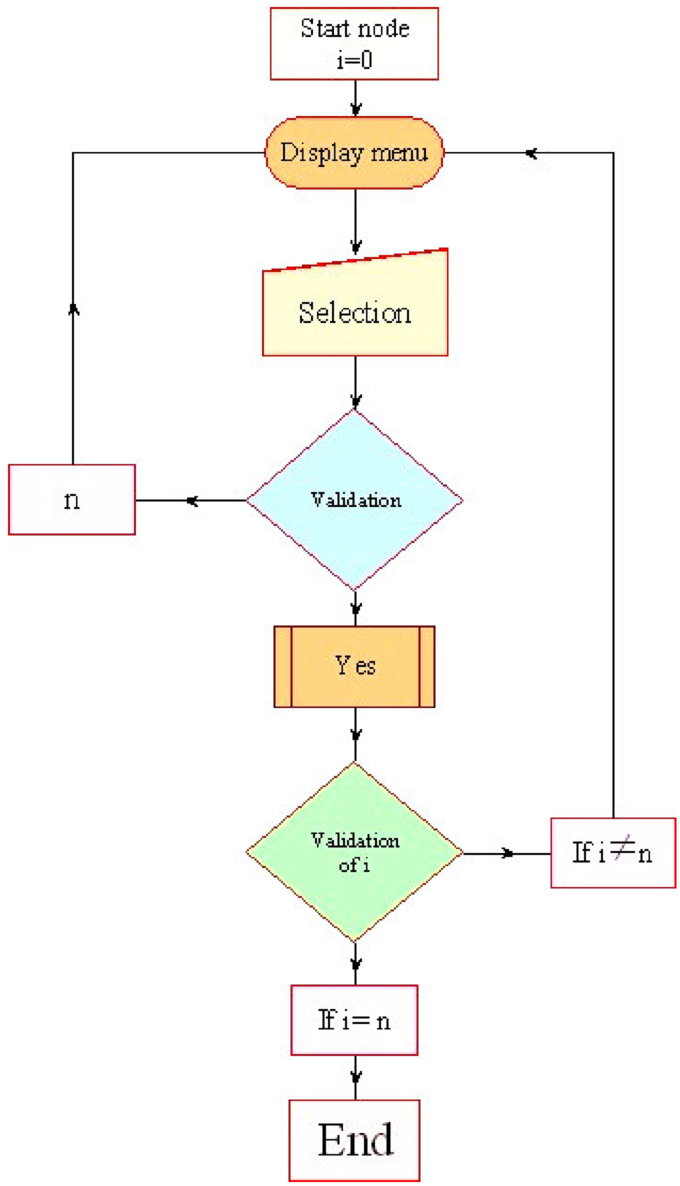

Figure 4-7 Control flow diagram of linear menu

Here, from start node to end node represents successful task completion. From start to end, one needs 'n' steps and 'i' represent the iteration taken to complete the task. Before execution programs or user check for validation or correctness, if it is not the case one has to return to the start node and repeat the process again.

4.5.2.2 Non-linear menu

Conventional menus list items in a linear array. A list has the characteristics of having a starting point and an end and a definite ordering between the items. The beginning and end items are special in the meaning while serving as anchors. Other items have president and successor relationships that help the user to locate items and structure the list. Non-linear menu convey different relationship among the items. To understand, for example rectangular layout conveys multiple dimensions and classes of related items. In addition to row and column location (a linear ordering), they convey similarity and neighbour relationship (non-linear diagonal ordering).

Non-linear menus have two advantages. First- visual recognition and spatial memory are powerful and efficient means that users have for locating items on the screen. The graphic representation conveys a context for choice and structure for visual search (Norman, 1991). Second- non-linear menu may be arranged to facilitate selection time. However small screen of PDA has little to do with selection time and target distance, it may be the matter of micro level research.

This above image demonstrates how a non-linear menu segments its menu options into segments of circle. These pie segments are then arranged in their circle around the point of activation. To choose a menu option the user moves the selection device in the direction of the required option. Each option is the same distance from the selection 'cursor' just the direction is different; therefore the quantitative ease of selecting each menu option, will be the same. In this case, repeated use of non-linear menus facilitates learning of menu options at a faster rate than using linear menus. The human body learns repeated muscular actions intuitively so the user can navigate menu options without having to learn explicitly the symbolic or textual labels of the menu choice.

In case of small screen devices like PDAs, representation of textual message as menu item is somehow difficult task simply because of its limited display size. Logical arrangement of menu item and then to represent it in symbolic labels is certainly a suitable alternative for small screen devices.

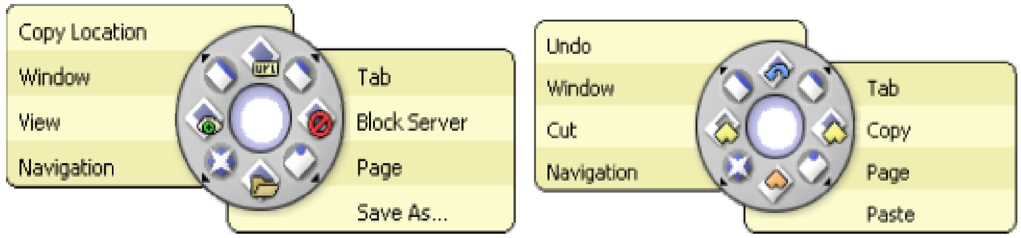

Figure 4-8 Example of non-linear pie menu

The pie- like arrangement of non-linear menu item as shown in above figure 4-8 have been implemented to Mozilla[58] based Firefox[59] web browser. The fact that pie menus do not scale as well above eight menu choices means that it is important that the design of the menus be well constructed to logically group together related menu functions into sub menus. Although this is a limitation it does help the design to conform to Millers assertion that seven menu items, plus or minus two, was the optimum number of items that could be processed by the average person (Miller, 1956). Although this limit has been contested, it is still a widely used measure in the design of human computer interfaces.

4.6 Indicators of complexity and their measurement

Complexity (Brown, 1982) appears in a large variety of forms. The best tasting are time and space complexity, but unfortunately many important natural problems have (or are believed to have) high time or space complexity. Fortunately, we often do not have to solve a problem exactly. It suffices to produce an approximate solution for a given problem instance. In such cases, the approximation complexity of the problem becomes important. If we say that user interface is complex, it is just an approximation. Nevertheless, a straightforward formulated problem. Therefore we can say, complexity of user interface is merely an approximation but a real problem and need to be solved. We have already said that problems itself may have varied time and space complexity. Of course, a user interface may be complex for one user but for other less or not at all. It may be much complex at start (of its use) but almost simple after its prolonged use (time effect). How much and when it is complex, is a factor which determines its complexity of use. The scale of complexity may vary from user

[58] Web browser offering full suite of integrated Internet applications including a web browser, e-mail client, address book, web page composer, Internet chat software and calendar application. (See details at: http://www.mozilla.org/about/)

[59]Next generation browser from Mozilla, currently under development, expected to simplify and speed up browsing experience. ((See details at: http://www.mozilla.org/about/)

to user and for what context they use it (compare with man-technology-organisation concept discussed in previous chapters). This is what we refer to space complexity of user interface problem.

Complexity of user interface is main keyword in our principal hypothesis. It is an approximation having both time and space complexity, and complexity may appear in several forms in a PDA device. Menu structure is one aspect that we want to measure. There are certain fundamental concepts to make it measurable- users satisfaction, efficiency, effectiveness, and productivity are some popular and common and frequently used for its measurement. Complexity of an user interface determines the quality of software (Boehm, 1978; Conrath & Sharma, 1992) that significantly affects user satisfaction (Doll & Torkzadeh, 1988; Melone, 1990) productivity (Bailey *et al.*, 1988), and effectiveness (Delone & Mclean, 1992; Gatian, 1994).

Therefore, we must consider what users perceive to be the major advantages of particular menu in PDA and what effect these perceptions have on overall user satisfaction. Unless, this issue has not been fully addressed, it would rather be ineffective as far as the software quality and usability of a product is concerned.

Now days, measuring these factors are not new in the research of small handhelds. For example, cellular phones are a widespread example of a menu-driven technical device whose, usage still imposes difficulties on many users (Ziefle, 2002) because of limited space and small sized display area. Ziefle (2000) studied usability, ease of use and learnability of three different small screen sized devices (Nokia 3210, Siemens c35i, Motorola P7389). The first independent variable referred to the complexity of the menu (depth/breadth of the menu tree) and navigation keys (number/functionality). She found the Nokia phone had the lowest and the Motorola the highest complexity.

The second independent variable was user expertise: 30 novices and 30 experts solved six telephone tasks. In order to assess effects of learnability, tasks were presented twice. Differences between the mobile phones regarding effectiveness, efficiency and learnability were found: Nokia users showed the best performance. The remaining two phones did not differ significantly, although the most complex phone was superior to the phone of medium complexity, which had the lowest performance.

Moreover, an effect of expertise was confirmed, though suboptimal interfaces were identified as lessening the advantage of expertise. Specific weaknesses of the tested phones were also discussed in the study. Similarly while conducting a doctoral research on non- linear manual for using cellular phone menu, Bay (2003) at the department of psychology, Aachen University of Germany found interesting to explore the effect of a spatial[60] manual on inexperienced mobile phone users when solving phone tasks.

Much of the research on user satisfaction has concerned users' satisfaction with specific features of a system (Doll & Torkzadeh, 1988; Iivari & Koskela, 1987) or system function (Bailey & Pearson, 1983; Baroudi & Orlikowski, 1988). Therefore, complexity of interface could here refers to the prioritization (users satisfaction) of one menu over other by users that means if one menu imposes more difficulty as compared to other, can be said more complex. In our hypothesis, when we claim that non-linear menu is better than linear menu it certainly requires to be confirm on the basis of certain parameters which are measurable. Degree of satisfaction is one measure to confirm the level of complexity (see Doll & Torkzadeh, 1988; Melone, 1990). (ISO9241, 1998) defines satisfaction as "the user's comfort with and positive attitude towards the use of the system". Rafaeli (1989) identifies satisfaction as "one of the most obvious outcome of increased interactivity". In the same way, Interactivity is also found to bring satisfaction, acceptance and motivation (Rafaeli, 1989; Szuprowicz, 1996). Increased level of interactivity will result in greater satisfaction and Greater satisfaction will result in higher assessment of value. We will be concerned of user satisfaction as DeLone, McLean (1992) refers to the overall user satisfaction. Seddon & Kiew (1994) measured independently of system quality and information quality, otherwise, the relationship between PDA/information quality, and user satisfaction would be an artefact of measurement, which is not our objective. Therefore, a well-formatted questionnaire with assessment sheet is used to measure the over all satisfaction.

To make distinction between two types of menu for a given task, effectiveness and efficiency are the other measurable criteria. Effectiveness (ISO 9241, 1998) is defined as the accuracy and completeness of the task with which users achieve certain goal. Error is the indicator of accuracy and time for the completeness. Less error made in one menu with their corresponding time value signifies its higher effectiveness as

[60] Non-linear

compared to other one. Higher the effectiveness indicates lower difficulty involved while using the menu.

Complexity also affects largely performance of a user e.g. if a user has to navigate through different depth of menu, complexity involved in menu organization can affect users performance to complete the given task. Linearly structured menus are often arranged in a hierarchical order of different depth level. This can be understood through an example of employee record maintenance in a university. Different depth of employee would be faculty-department- academic and non academic- guest- etc. which is as illustrated in figure 4-9.

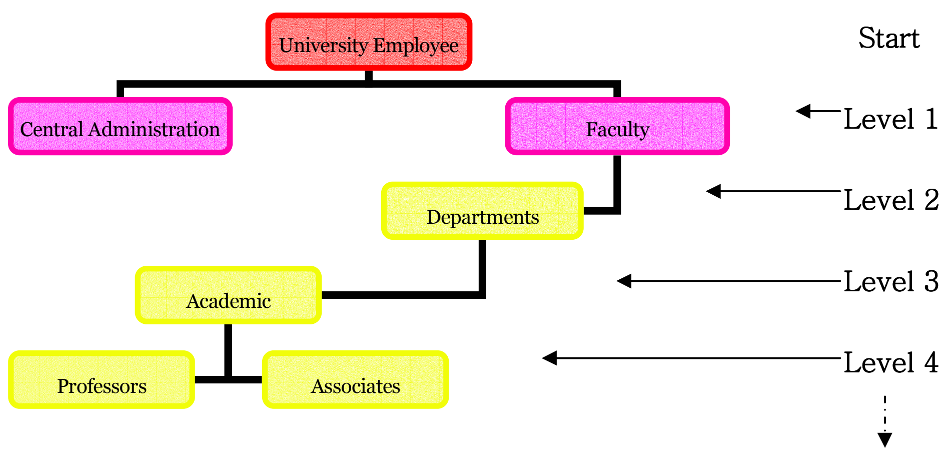

Figure 4-9 Representation of depth level in a linear menu

If we consider minimum of 'k' options at each level, we will have k^n items (where k is the no. of options at each level of menu & n is the no. of depth level) at k^{th} level menu to show on the screen. In this case, $2^4 = 16$ options to show at 4^{th} level depth of menu. This is not a simple task to design a menu interface for a small screen of PDA to show 16 options without compromising with their visibility and clearness. (However, word length of each menu is not included). It is already reported that many researcher and we have already discussed (chapter 1 & chapter 3) that users were frustrated and inaccurate while working with small screen interfaces.

We believe that due to linear arrangement of a menu depth level cause a serious effect on users performance. This in turns results into lower productivity and efficiency of work. To measure complexity of this nature in a user-interface one need to quantify these measures.

Efficiency and productiveness are reliable measures to determine the difference at different depth level. (ISO 9241, 1998) defines efficiency as the relation between the accuracy and completeness with which users achieve certain goals. Productiveness can be defined as the ratio of productive time taken to the total time taken in completing the given task. These measures are explained in research methodology chapter.

4.7 Summary

In this chapter, we have discussed the key terms involved in the study. At first, we have discussed users in context of information science and found the definition relevant to our objective as ***"an individual who utilise technology strategically, for a number of different – but integrated – professional and/or personal purposes, in a number of different social environments and relationships"***. In this definition, technology means a device such as PDA or mobile phone. It serves our purpose to select subject who uses the device for professional or personal purposes. Further evolution of user interface is discussed to get the appropriate definition for small screen devices and concluded that user interface should have a *format or structure (body, header and trailer) displayed on the screen to provide options or commands for the user to perform desired actions to run an application.* It helped us to understand menu used in small interfaces and their possible structure of representation. Linear menu is discussed in detail and as a result, a concept on non-linear menu suitability is justified. Finally, to measure complexity of an interface certain indicators have been discussed explicitly. User's satisfaction, effectiveness in terms of time and error and performance in terms of efficiency and productiveness, found to be quite relevant in present research aim.

Chapter 5

Hypotheses

While interacting with a machine, there are certain psychological aspects of human beings, which influence them to handle that machine in their own way depending upon their pre-determined psychological use behaviour. In case of small screen mobile devices interface is the very first point where user starts to communicate with the device or system. To reach the maximum user friendliness while interacting with such systems, menu organisation of user interface is the subject of concern; how efficient user selects the menu to reach or fulfil their need. Design of simpler and understandable interface will increase the usability of devices and consequently better man machine interaction. To achieve this some researchers already practiced alternative form of menu representation e.g. Bederson et al. (2003) used fisheye[61] style for calendar application in PDAs. This led them to develop DateLens[62], a novel calendar interface for PDAs designed to support complex tasks. It uses a fisheye representation coupled with compact overviews to give the big picture in a small space. The interface also give users control over the visible time-period, as well as supporting integrated search to discover patterns and outliers.

However, fisheye techniques proved rarely useful for interfaces for PDAs and other devices with small displays. Other alternative was developed by Björk et al. (1999) who used "flip zooming" to display web pages and then personal information including calendar data (Björk, 2000) on a PDA as demonstrated within their PowerView application. Flip zooming consists of presenting one medium-sized focus page and several tiny pages in the periphery that can be used for navigation. At a high

[61] A fisheye menu applies traditional fisheye graphical visualization techniques to linear menus. This provides an efficient mechanism to select items from long menus to select data items. Fisheye menus dynamically change the size of menu items to provide a focus area around the mouse pointer. This makes it possible to present the entire menu on a single screen without requiring buttons, scrollbars, or hierarchies.
[62] A calendar interface for PDAs, to better support more complex tasks such as picking a good weekend to go camping, counting the number of Mondays in November, finding the start and end dates of a trip. These are instances of tasks that we classify more generally as scheduling, navigating and counting, and searching, respectively.
[DateLens is available for download at http://www.cs.umd.edu/hcil/datelens]

level, the basic approach of flip zooming is similar to DateLens. However, DateLens differs from flip zooming in that flip zooming is designed to support hierarchical textual data while DateLens supports tabular data with a natural visual abstraction. Furthermore, Bederson, Clamage, Czerwinski & Robertson (2003) reported that flip zooming has system-defined viewpoints while DateLens allows users to define views. Finally, DateLens adds two important new features: integrated search and animated transitions.

Another approach of developing interface is spatial or non-linear hypertext systems that support early stages of linear-information authoring, such as paper writing and movie editing etc. Hypothesised non- linear structure of menu organisation uses partially the benefit of spatial (non-linear) hypertext visualization principal. Spatial hypertext systems were designed based on the ART[63] principle, which emphasizes the importance of visual interaction and the power of external representations. The system uses spatial hypertext not as a medium for representing final artefacts but as a means of interacting with linear information during an authoring process. In most spatial hypertext systems, spatial positioning of objects is used as media with which people incrementally generate, organize and structure information (Shipman et al., 1999). The space is used to let people put objects in a flexible manner, leaving structure "implicit and informal" (Shipman, Marshall & Lemere, 1999). They help users gradually define and fix relationships among objects using emerging structures. Yamamoto et al., (2002) showed semiotic interpretation of spatial hypertext as a representation, and innovative use of spatial hypertext as an instrument to compose information, rather than as an information medium.

Trying out an alternative structure of menu representation is not new but very rare in case of PDAs. As we have stated in chapter 3 (Research problem description) and later in chapter 4 (Theory), size of display and no. of items involved in linear structured menu makes it complicated to work with. We believe that non-linear representation of menu is simpler to understand and work and therefore less complex.

The following hypotheses are made to relate user interaction with the device: these hypotheses are made to carry out an empirical study to compare the effectiveness of linear and non-linear menu arrangements. Assumptions made are

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[63] Amplifying Representational Talkback

equally discussed with respective hypotheses.

First hypothesis: Non linear menu structure decreases interface complexity in small screen display interfaces

The main reason for the enormous popularity of mobile devices is their small physical size and portability. This portability, however, brings with it limitations in terms of input and output capabilities, making the interface design of such devices very challenging (Masoodian & Lane, 2003).

Designers of interfaces for handheld devices have come to realise that novel user interface design for small screens is far from straightforward adaptation of techniques developed for traditional large screens to their smaller counterparts (Holmquist, 1999).

As PDA has restricted display size linear menu structure, e.g. using pull down menu may result into user's frustration and he finds sometimes lost in the process of selection. To attain the goal he is then forced to repeat the process again from the start. Most of the interface objects used in desktop computing environments - pull-down or popup menus, multiple windows, icons - consume a great deal of valuable screen space and are not appropriate for a PDA screen (Kamba, Elson, Harpold, Stamper & P., 1996). With the use of graphical user interfaces, non-linear menu can simplify the user interface for specific application. With the increased "look and feel", display of options could make the selection process simple and efficient. Considering example of city map and street list: if user is asked to choose a street – either he has option to scroll the whole list in case of linear menu structure or by pointing out the city area he could be able to choose the street in less time as in case of linear menu.

Linear menu structures are based on theory of selection whereas non-linear menu structures are based on theory of rejection i.e. sorting out irrelevant part of information or data from small sized screen. Conventional desktop has bigger screen size and higher processing capacity; huge amount of information can be stored and displayed easily. Whereas in case of PDA where screen size is considerably small and processing capability is also greatly restricted it becomes necessary to utilize the strategy that at particular time of application only useful information or data is available for the use and rest keeping out from the screen and even from memory. Menus are nothing but a set of data stored in PDA's memory and be displayed whenever asked by user. Calling the list of all restaurants in Flensburg certainly takes more spaces in memory and reduces the speed of operation as compared to calling the list of restaurants on that area only where user is staying at that time.

Secondly, equal distance from one node to other (see fig 5-1 & 5-2) in case of non-linear menu enables user to work easier than linear menu.

Interface complexity has to be measured in terms of user's satisfaction, task completion time and error committed during task completion. Therefore, decision on interface complexity is made through further sub- categorising the hypothesis i.e. non –linear menu is less complex if

Users satisfaction score for non-linear menu > users satisfaction score for linear menu	
Task completion time in non-linear menu	**< Task completion time in linear menu**
Error committed in non-linear menu	**< Error committed in linear menu**

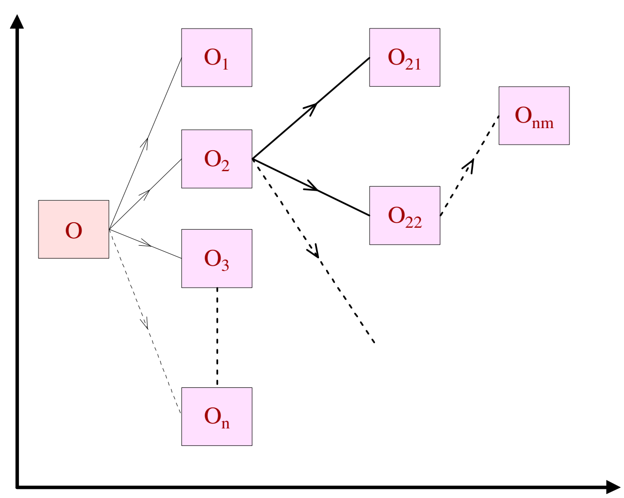

Figure 5-1 Linear structured menu schematic details (options- depth relationship)

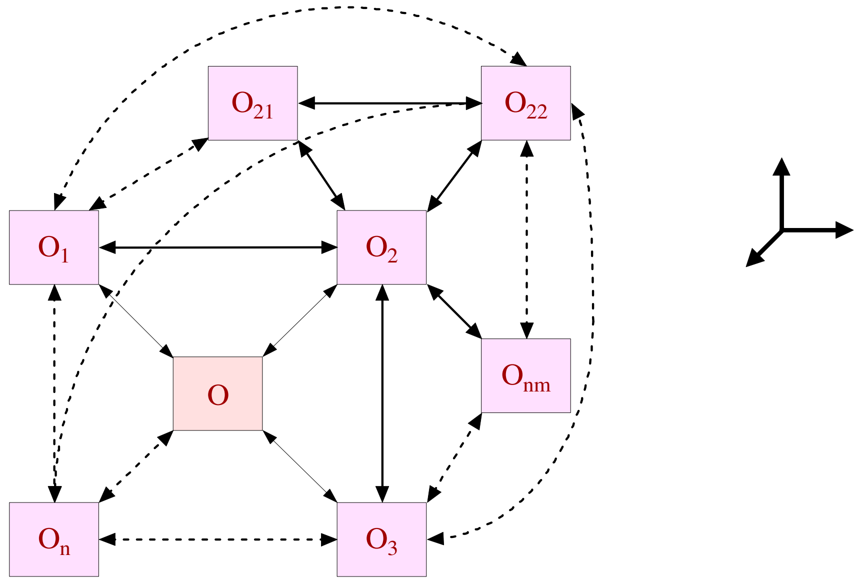

Figure 5-2 Schematic representation of non-linear menu with equal depth

Second hypothesis: As menu depth in linear menu increases users performance decreases

The development of a large menu-based interface to an operating system posed a number of interesting user interface questions. Among those were how to determine the user's view of the relationships among the myriad of functions in the system, and how to reflect those relationships in a menu hierarchy (Tullis, 1985). Kiger (1984) reported on an experiment, which investigates breadth/depth tradeoffs for menus and tree structures in user interfaces for information retrieval systems. He used retrieval time and accuracy as the basic measures of performance.

Linear menus have only one path. Menu frames are presented in a preset order for parameter specification or for data entry. Two main problems with linear menus are that (a) the user may need to go back and change an answer in a previous menu, and (b) the user may want to answer the question in a different order than preset by the system. Solution of first problem can be handled using an 'undo[64]' command that jumped back to a specific frame, but in general, it is rather awkward and confusing for the user. This is the case when only two level of menu are in consideration; research

[64] Compare with Microsoft word programme menu- edit- Undo

shown in desktop application is rather difficult for user to operate after 4th level menus. It becomes much difficult for the PDA user to operate even after second level menus. Moreover, there are certain other factors such as font size, length of menu items, no. of items to be displayed on the screen etc. that does not allow much space for a designer of small interface to develop linear menu without compromising with the quality of interface. As a result, user's performance in terms of effective task completion and therefore productiveness of work drops to a certain extent.

User's performance has to be measured in terms of efficiency (**η**) to complete the task and productiveness (**ρ**) of users with menu. Henceforth, hypothesis let described in following way:

Efficiency of users at lower depth > Efficiency of users at higher depth

Productiveness of user at lower depth > Productiveness of user at higher depth

Menu depth formulation seems to be her ambiguous in nature, so we make it clear that if there are 3 level of menu depth: menu depth at second level would be considered as lower than menu depth at third level.

Third hypothesis: Non-linear menu suits better for technicians

In previous chapter "theory" [4.2.1], we have conceptualised user as individuals who utilise technology strategically, for a number of different – but integrated professional and personal purposes, in a number of different social environments and relationships. The hypothesis of suitability of non-linear menu for organisational task completions stands here because consumers use the technology change with context. Studies of other technologies and their users indicate that this conceptualisation may not unique to the case of PDA. There are several other examples of technologies that essentially evolved for one purpose but found more useful in some other areas. For example, Frissen (1994) claims that phones have gone from being household appliances to a highly personalised communications medium. While research on patterns of diffusion can tell us who consumes them, and other qualitative and theoretical studies can indicate the delicacy and complexity of that user's perception, patterns of use are another question altogether. How, where and when individuals use their mobile devices is characterised more fully in the social science literature by qualitative studies which explicitly address modalities of interaction and communication.

In the context of work, the ‘adjustment’ of space and time through technologies changes patterns of work such that ‘offices’ become ‘mobile and extensible’ sites where interactions reorder and facilitate decentralised work and organisational relationships. Mobile telecommunications, for example, can be used to do ‘assembling work’, to make a dispersed spatial and organisational world relatively predictable and to extend a person and their organisational role. Laurier (1999) demonstrated in a study of mobile salespeople how mobile communications allowed the appropriation of the client’s fixed space, drawing it into the operational space of the organisation. In simple words, this means that salespeople can contact their own organisations via mobile networks while they are physically located in the space of one of their clients. The interactional properties of particular devices and the changing communications make possible, therefore changing users orientations. With due effect, changed interface in a PDA, may better suit to fulfil organisational or professional need of a user. Context of use, type of interface applied and user’s background altogether may induce an effect of increased/reduced interface complexity of devices like PDA. This hypothesis is based on our MTO conceptual foundation and need to be tested against professional background, age and gender of the user.

Chapter 6

Research Methodology

6.1 Introduction

This chapter is dedicated to the overall methodology adopted during the course of research starting from literature review to the evaluation of experiment. This is divided into five major sections i.e. study methodology, evaluation methodology, measurement methodology, experiment design and decision logic for hypothesis testing. Study methodology explains appropriate method to be adopted for the study as whole. Evaluation methodology discusses empirical walkthrough and statistical evaluation details whereas measurement methodology discusses the criteria and mode of measurement to be done for their accurate evaluation. In experiment design sections, simulation detail, test environment (vie. test plan and task scenario), data collection and questionnaire details are explained. Selection of prototype used for simulation of menu interface is also discussed in this section. Finally, a decision logic table is prepared for the ease of understanding to know how the hypothesis is validated or invalidated.

6.2 Study methodology

Kjeldskov & Graham (2004) examined and reviewed study methods applied within the field of mobile human-computer interaction. The purpose was to provide a picture of current practice for studying mobile HCI to identify shortcomings in the way research is conducted and to propose opportunities for future approaches. They revealed of significant trends with a clear bias towards building systems and evaluating them only in laboratory settings among action research, case studies, field studies and basic research methods.

The study of human computer interaction for mobile devices is a relatively young research field in which commercially successful devices have only been available for less than a decade and leading conferences have only a few years of history. In young research fields, there is often a tendency to be highly opportunity and technology driven and to focus primarily on producing solutions while reflecting less on methodology. As a research field matures, examining how the research is being conducted and reflecting on the impact of this on the knowledge being produced is necessary in order to be able to understand and influence the future direction of the field. So far, this has not been done consistently within the community of mobile HCI and consequently little knowledge on a methodological level exists about the research field.

Research on mobile devices are actually deep rooted in information science, where focus and reflection on research methodology has been a key subject within information system research for decades (Galliers, 1990; Wynekoop & Conger, 1990; Basili, Selbi & Hutchins, 1986; Benbasat, Goldstein & Mead, 1987; Myers, 1997). A number of frameworks for describing and categorizing information science research methods have been developed and which could be relevant in relation to discussions of mobile HCI research (Jesper Kjeldskov and Connor Graham, 2004). Wynekoop and Conger (1990) demonstrated a generally usable (and relatively simple) approach of research methods and applied in a two-dimensional matrix relating research methods and research purpose, providing a picture of current research practices.

	Method	**Strengths**	**Weaknesses**	**Use**
Natural setting	*Case studies*	*Natural settings Rich data*	*Time demanding Limited generalisability*	*Descriptions, explanations, developing hypothesis*
	Field studies	*Natural Settings Replicable*	*Difficult data collection Unknown sample bias*	*Studying current practice Evaluating new practices*
	Action research	*First hand experience Applying theory to practice*	*Ethics, bias, time Unknown generalisability*	*Generate hypothesis/theory Testing theories/hypothesis*
Artificial setting	***Laboratory experiments***	***Control of variables Replicable***	***Limited realism Unknown generalisability***	***Controlled experiments Theory/product testing***
Environment independent setting	*Survey research*	*Easy, low cost Can reduce sample bias*	*Context insensitive No variable manipulation*	*Collecting descriptive data from large samples*
	Applied research	***The goal is a product which may be evaluated***	***May need further design to make product general***	***Product development, testing hypothesis/concepts***

Figure 6-1 Mobile HCI research methods comparison

We found six possible definitions extracted from research methods matrix (Wynekoop and Conger, 1990) relevant in mobile HCI research practice with supplementary input from general references of information science.

From figure 6-1, it is clear that, case studies could be used to provide rich data explaining phenomena involving mobility or the use of mobile devices in context. They are particularly well suited for research focusing on describing and explaining a specific phenomenon and for developing hypothesis or theory through, for example, applying grounded-theory approaches. Case studies are much time demanding and generalising of findings can be difficult. Whereas, in relation to mobile HCI research, field studies could be applied for either informing design or for understanding of mobility by ethnographic studies of current practice or for evaluating design or theory by conducting experiments in realistic use settings. In this case, disadvantages include limited control of experiments and complicated data collection compared to, for example, experiments in laboratory settings. In case of action research, since the researcher takes part in the phenomena studied remaining objective can be difficult. In mobile HCI research, action research could be used for extending field or case studies by researchers participating actively in real world activities involving mobility, introducing different solutions or theories "on-the-fly" as well as evaluating their effects and/or validity. Surveys suffer from providing only snapshots of studied phenomena and rely highly on the subjective views of respondents. It facilitates only information being gathered about user needs and requirements for understanding a phenomenon, building theory or developing systems.

Weighing all the pros and contras of these methods, which are applied in mobile HCI field we found that laboratory study and applied research technique fits for our purpose. According to Wynekoop, & Conger (1990), applied research builds on trial and error based on the researchers capabilities of reasoning through intuition, experience, deduction and induction. The advantages of applied research is that it is very goal directed and (typically) results in some kind of product being produced, which can be evaluated against the initial goals. Kjeldskov & Graham (2004) concluded that, in mobile HCI research, applied research is relevant in relation to design and implementation of systems, interfaces and techniques, which meet certain requirements for performance, user interaction, user satisfaction etc.

Laboratory studies are characterized by taking place in a controlled environment created for the purpose of research. Laboratory experiments do not necessarily take place in dedicated "laboratories" and can be conducted in various controlled environments such as in an office (Tang, J., Yankelovich, N., Begole, B., Van Kleek, M., Li, F. & Bhalodia, 2001) in a corridor (Bohnenberger, T., Jameson, A., Kruger, A. & Butz, A., 2002) or in a simulator (Kjeldskov J. & Skov M. B., 2003). Laboratory experiments facilitate various types of data being collected using different experimental methods depending on the style of subsequent analysis desired. While traditional quantitative measurements of factors such as error rate and task completion times, data are collected and therefore suitable for statistical methods of analysis. The major advantages of laboratory studies are the opportunity to focus on specific phenomena of interest and a large degree of experimental control in terms of manipulation of variables before and during the experiment through for example assignment of test subjects and exposure to different treatment variables (Kjeldskov & Graham, 2004). In addition, laboratory experiments are typically highly replicable and facilitate good data collection. Disadvantages include limited relation to the real world and an unknown level of generalisability of results outside laboratory settings. In mobile HCI research, laboratory experiments are suitable for evaluating design ideas, specific theories about design and user interaction in controlled environments with little or no interference from the real world.

6.3 Evaluation methodology

In the social and natural science, statistical methods based on probabilistic reasoning are usually employed in the evaluation of empirical studies. In practice, the accumulation of evidence for or against any particular theory involves planned research designs for the collection of empirical data. Several typographies for such designs have been recommended, one of the most popular of which comes from Campbell (Campbell & Stanley, 1963). They are responsible for popularising the commonly cited distinction among pre-experimental, experimental, and quasi-experimental designs and are advocates of the central role of randomised experiments in educational research.

The hallmarks of an experiment to Campbell and Stanley, among others are

(a) Random assignment of cases to comparison groups,

(b) Control of the implementation of a manipulated treatment variable, and
(c) Measurement of the outcome with relevant & reliable instruments. Controlled experimentation allows for replication of the conditions of the experiment so that independent researchers can attempt to repeat the results of the experiment. In contrast, non- experimental studies may use convenience of samples, comparison groups formed by post-hoc matching and similar procedures.

Campbell and Stanley (1963) provide a framework for evaluating the limitations that various types of research studies pose with respect to inferring a causal link between independent (treatment) and dependent (outcome) variables. They posit a necessary relationship between the validity of an individual research study and the generalization of results from this study to wider populations. Empirical methods are the means by which scientists gather information about the world in order to develop theories. These include laboratory experiment, applied research and other ways in which scientists assess theories. These are now widely recognised to constitute much of what is loosely called '**scientific consensus**', as some theories are not amenable to direct experimental invalidation, or indeed controlled experiment. It may also be conducted according to hypothetico-deductive procedures, such as those developed from the work of R. A. Fisher (Fisher, 1959).

In this method, a hypothesis is devised from which can be deduced certain explicit, observable predictions. Observations that run contrary to those predictions are taken as evidence against the hypothesis; observations that are in agreement with those predictions are taken as corroborating the hypothesis. It is then supposedly possible to compare the explanatory value of competing hypothesis by looking to see how well they are sustained by their predictions.

Since it appears that virtually any observation can be seen as corroboration of any hypothesis, the choice of which observations the scientists involved should take seriously seems to be open, rather than a matter of the application of a strict method. The argument has also been taken as showing that both observations and theories are embedded in our overall understanding (holism), and so that it is not possible to make truly independent observations.

Such evidence is called a falsification of the hypothesis. However, under the theory of confirmation holism it is always possible to save a given hypothesis from falsification. This is so because any falsifying observation is embedded in a theoretical background, which can be modified in order to save the hypothesis. In our hypothesis non-linear menu decreases interface complexity of small screen devices, an evidence to falsify certain condition of interface complexity in linear menu confirms that at least one aspect in non-linear menu decreases its complexity to use, as compared to linear menu.

The first hypothesis have three major parts i.e. Menu type, interface complexity and user (in simple words we can say that, "*particular menu type in a PDA interface make interface more complex for certain user*"). We have two comparable (independent) variables i.e. linear and non-linear menu with test (independent) variable i.e. students & technicians to assess change in complexity by fixing measurable dependent variable (satisfaction, time & error). Second hypothesis of depth level is nothing but to re-confirm or validate that linear menu is complex as because increase in menu depth surely affects user's performance. In our third hypothesis, we will test if there is any effect of professional background, gender and age visible in either of menu art Independent variable. Productiveness and efficiency are the dependent variable in this case.

We are mentioning here valuable metrics and measurement that have been used directly or indirectly to analyse and evaluate our research hypothesis.

6.3 Measurement methodology

Metrics have a long history of successful application in software engineering (Card & Glass, 1990). Metrics are quantitative indices that measures or estimates some factors or dimensions of usefulness of proposed interface, accordingly one can validate established hypothesis. These metrics are relatively recent development effectively used by even usability engineers to maintain software quality. However, metrics are not ultimate solution to software usability problems (Constantine & Lockwood, 1999), rather they are effective tool for the researcher to guide them towards more usable solutions. Following metrics have been used to confirm the comparative quality of non-linear menu over linear set of menu in PDA display.

6.3.1 Preference metrics

Quantitative measures of user interface system based on subjective evaluation by users and their impressions on the user interface system, including personal preference, aesthetic appeal, comfort, and satisfaction. This metrics is most popular and widely used by practitioners but one must be careful here because subjective evaluation has both advantages and disadvantages. Sometimes user may say, for example, that they prefer particular designs even though those designs are actually difficult to use. Nonetheless, subjective impressions from real users cannot be ignored altogether.

The concept of User Satisfaction can be traced to the work of Cyert and March (1963), who suggested that an information system which meets the needs of its user will reinforce satisfaction with that system. If the system does not provide the needed information, the user will become dissatisfied and look elsewhere. Although ideally one would like to evaluate the effectiveness of an information system based on its degree of use in decision-making and the resultant productivity benefits, this "decision analysis" approach is generally not feasible. Satisfaction of users with their information systems is a potentially measurable, and generally acceptable, surrogate for utility in decision-making.

The construct of user satisfaction has been operationalised in many different ways. Several studies employed single-item rating scales (Barrett *et al.*,1968; Lucas,1976) such scales have been criticized as unreliable (Larcker & Lessig,1980; Nunnally,1978). Single-item scales also provide little information as to what the user finds dissatisfying (or satisfying) and are thus of limited utility outside a research setting. Multiple-item user satisfaction measures have become increasingly common.

We will use a defined scheme for assessing user preference by applying two sketches of layout and asking them which the user most prefers. In this case we draw a list of questions to be rated on a scale of 1 to 5. Custom-designed questionnaires or rating scale will be useful here while there are highly particular issues to be settled and where there is the interface or its domain of application is unusual.

Like user interface design, questionnaire design is both an art and a science, subjective assessment made by user can be complex, incorporating any number of factors that may need to be carefully separated and evaluated.

However, there is no standardised set of questionnaire available to assess mobile or small screen interfaces; we have developed our own set of questions. This questionnaire is not similar to those, which have actually been evolved to assess desktop user interfaces, basic principles are taken from them. There is two widely recognised standard set of preference metrics available: software usability measurement inventory (SUMI)[65] and subjective usability scale for software (SUSS). In contrast to SUMI, that is more appropriate for usability testing, SUSS is a better choice for research purpose using only ten carefully constructed item and measures six key elements of user interface namely:

Valence—liking or personal preference
Aesthetics—Attractiveness
Organisation—graphical design and layout
Interpretation—understandability
Acquisition – ease of learning
Facility—overall ease of use

We have used these key elements in our questionnaire to assess the satisfaction level of the two menus.

6.3.2 Performance metrics

Quantitative measures of user interface system based on actual performance of users working with a system, simulation, or functional (working) prototype either in laboratory setting or under field condition in a normal work environment.

In qualitative research, some questions are answered only through actual use of working system, and it is the function of viably thought research methodology to simulate the condition of use sufficiently well to yield dependable answers. **Performance metrics** are indices of various aspects of how users perform during actual or simulated work. A variety of aspects of performance can be measured, such as time to complete a task or set of tasks, error rates, or the frequency of requests for help needed. These performance metrics have been used to determine the level of complexity (time and error analysis).

Quantitative measures that predict system usability in practice based on countable or measurable aspects of a user interface design.

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[65] Was developed as part of the ESPRIT project (Porteous *et al.*, 1993) and has a 50-item questionnaire that includes five subscales measuring different subjective aspects of software usability viz.
Affect—How much the user likes the design,
Efficiency—How well the software enables productive use,
Helpfulness—how supportive the software and documentation are,
Control—how consistent and normal the software response is
Learnability—how easy the software is to explore and master

Measurement parameters

Parameters to be measured in a usable, effective and efficient to **meet particular requirement** are valuable research tools. I am formulating three foundry parameters to be considered as backbone of good research practice involved in user interface evaluation. These performance parameters are an honest and reasonable approach to measure complexity. For example, it seems logical to assume that a screen with more menu item is more complex hence difficult to use as compared to one with less menu items. These parameters have to measure user interface aspects that depend on the concept and actions of visual components and how users make sense of the components-interrelationship. Additionally, these parameters deals with fit between the various tasks and a given menu structure in terms of its content and organisation. To meet entire requirements certain criteria are inevitable.

6.3.2.1 Measurement criteria

Effective measures, metrics, parameters should, of course reliably predict important aspects of the user interface in actual application such as task performance times, learning time, or error rates. A strong, simple conceptual basis means that one who thinks of new, innovative mode of user interaction can readily understand the rationale for design, metrics or parameters and see that what makes one concept better than another in terms of those does. These can be reached with following criteria's, means if one

- Have a strong rational and simple conceptual basis,
- Easy to calculate and interpret,
- Have sufficient sensitivity and ability to discriminate from other one,
- Effectively predict its importance and usefulness,
- Indicates relative quality of performance

A good conceptual basis makes it easier for researchers to understand how differences in measured levels reflect differences in architecture and structure. Of course, metrics, parameters or measures that can be computed /calculated from visual appearance or simulated prototypes will not be less important than one that requires fully or partially working system. Interesting is also here to see the sensitivity and uniqueness of one concept to other in some absolute case. An absolute assessment can indicate whether concept itself qualifies for further refinement or not and if one can easily distinguish it from similar designs.

6.3.2.2 Performance measurement

Quantifying and summarizing important aspects of actual usage either under controlled laboratory conditions or within an ordinary work environment can measure performance. In 1994, some usability professionals and research entities validated practical suite of quantitative metrics for designing and guiding the user interfaces. These metrics are simple to use, conceptually sound, and have clear- transparent rational principles of appropriateness. Comparing it with usability testing (Bevan & Macleod, 1994) advocated such kind of quantified performance measurement and found it both simple and effective. I am listing here four measures of performance that can be quantified according to need.

I. **Elapsed time (T):** Elapsed time is simply the time taken to complete the given task successfully. It can be sub-divided into two parts viz. productive time and unproductive time.

$$\mathbf{T = T_p + T_u}$$

Where T_p = Productive time &

T_u = Unproductive time

Productive time is defined according to the nature of task. In our case, productive time is the time taken to move from one menu item to other.

II. **Error (E):** Error is defined as the false and undesired actions performed by the users. Any deviation from essential path to follow to complete the given task may result into error. The clear examples of errors are rollback, undo command, and unnecessary clicks on screen etc.

III. **Efficiency:** Efficiency (η) is a simple measure to know how strongly a given user interface approximates with the ideal expressed in the essential use case representation. Constantine & Lockwood (1999) described the essential use case as an ideal against which the actual interaction with a given design can be compared. However, Efficiency precisely is a ratio of the essential length to the endorsed length, that is, the ratio of the number of user steps in the essential use case descriptive to the number of enacted steps needed to perform the use case with a particular user interface:

$$\eta = \frac{S_{essential}}{S_{enacted}} \times 100$$

$S_{essential} =$ No. of essential steps required completing the task (narrative case)

$S_{enacted} =$ No. of user's actions required. (According to the counting rule established for enacted steps)

Here, one must understand how to define essential steps? In addition, what they are? These are narratives of user intention, to understand it exactly let us consider an automatic teller machine (ATM) interface in bank. It has three (3) essential steps: identification, selection and getting money.

Whereas enacted steps are real user actions performed with the interface, and can be better understand taking the same example of ATM. Task to get money involve following enacted steps-

Step 1. Entering data into one field terminated by enter key, a tab, or some other field separator,

Step 2. If there is some unneeded field, skipping it by tabbing or by means of other navigation key,

Step 3. Selecting a field, an object, or group of items by clicking, double clicking or with a pointing device,

Step 4. Selecting a field with keystroke or series of keystrokes,

Step 5. Switching from keyboard to pointing device,

Step 6. Acting upon command button,

Step 7. Selection of menu by pointing device,

Step 8. Prompting an action such as activating menu item,

Just to understand the efficiency in this case, we have 3 essential steps as mentioned above and 8 enacted steps that means, essential efficiency of

$$\eta = \frac{3}{8} \times 100 = 37.5\%$$

Let us consider here once again diluted enacted case to make efficiency clearer – optimised enacted steps would be:

Step 1. Insert card,

Step 2. Enter **PIN**[66],

[66] Personal identification number

Step 3. Select the desired menu,

Step 4. Take card out,

Step 5. Get the money.

Henceforth, Efficiency in this case will be

$$\eta = \frac{3}{5} \times 100 = 60\%$$

While efficiency compares 'enacted steps' to the 'essential steps required', the results are dependent on having an ideal use case model. Poor or deficient user case may look like more efficient, so in practice, the use case narrative should be reviewed for further simplification before calculating Efficiency.

In real research practices, although, the degree of simplification will not affect comparisons of different design as far as the efficiency is concerned, if it is calculated for the same use case.

IV. Productiveness: is simply defined as the percent of total subject time spent productively:

$$\Pr oductiveness = \frac{T_{total} - T_{unproductive}}{T_{total}} \bullet 100$$

Where

T_{total} = Total time spent on task,

$T_{unproducti\ ve}$ = Unproductive time

Unproductive time includes all time spent seeking help, using the help system e.g. referring documentation, searching or scanning for needed features. It also includes time spent in undoing or redoing actions.

In our test case time taken to use menu was considered the productive time keeping rest of the things such as typing, thinking, searching etc. away.

Last two metrics have been used to test our second hypothesis, whereas first three in altered form to analyse first hypothesis.

6.4 Experiment design and details

We are employing here deductive- quantitative approach to attain goal of research. The possible model for the research design will follow the approach suggested by Bohnsack (1993) and Lamnek(1995) as illustrated below in figure 6-2.

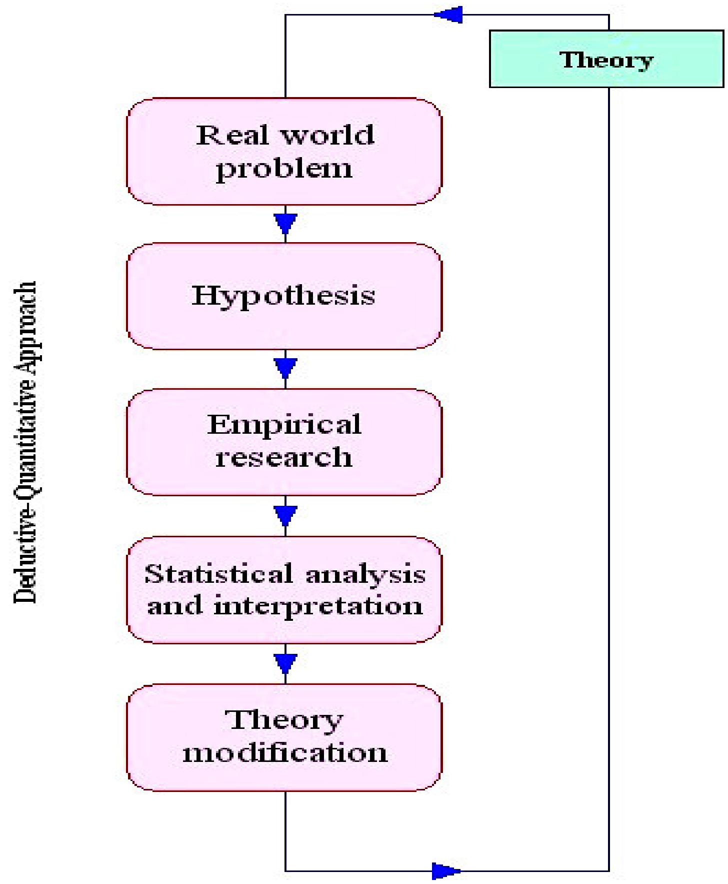

Figure 6-2 Deductive-quantitative approach of research design

Theory is to be understood as "People are using small screen devices encompassed with complex menu". The interface in such devices is complex for many users are a real world problem (see chapter 3: problem description). We believe that alternative structure of menu (non-linear) results into less complexity (see detailed hypothesis in previous chapter). We also suppose that alternative menu structure (non-linear) used by specific group of people (e.g. technicians) in an organisation could be more usable. We are performing empirical research on two group of sample with varied menu structures.

Experiment is mainly evaluated by using

a) **Statistical analysis:** using difference of mean, analysis of variance with significance test

b) **Storyboard assessment:** i.e. analysis of user's actions performed for different tasks.

Data on time, error and steps taken to complete the task is recorded and stored in SPSS[67] table for further analysis. Questionnaire was analysed for satisfaction score and stored in databank. Efficiency and productivity were calculated by using formulae already explained in this chapter earlier.

6.4.1 *Questionnaire detail*

In our research, simulation itself is a self-recording tool, where user's actions and interaction is recorded. A thoroughly designed questionnaire has been applied for data collection. This questionnaire has been used for satisfaction measurement and was based on standard subjective usability scale for software (SUSS). Five key elements viz. valence, aesthetics, organisation, interpretation, acquisition (see 6.2.1 of this chapter) were covered in individual questions after each task. Facility i.e. overall ease of use was asked in a form of final questionnaire.

There are six Questions after each task rated on a scale of 1 to 5 (1= fully agree…. 5= not at all). Minimum score of one and maximum of 5 points have been given for each question. In this way after each task user were able to give a maximum rating of 6x5 = 30 points. Final questionnaire (for overall ease of use) had also five questions with same rating scale but with doubled point. Maximum of 10 points for each question gives users ability to rate with maximum of 10 x 5= 50 points. There are three tasks in each menu with maximum score of 30 x 3 =90 points followed by final rating with maximum rating of 90 points. That means a user could have given maximum of (6 x 5 x 3) + (10 x 5 x 1) = 140 points for each menu type. (See appendix B)

6.4.2 *Prototype simulation details*

We have already defined and discussed prototype in Chapter "Theory". In the following, we are discussing prototyping technique and selection criteria for simulation prototype. Kiljander (1999) describes the experience of using different user interface prototyping methods and tools in designing user interfaces for mobile handset at Nokia. He concluded that, "Prototyping is one of the core activities in human- centred design for mobile handset". Bonner (1997) describes the challenges related to designing intelligent consumer and domestic product interfaces. Among the

[67] Widely used statistical analysis software application in social research

research question are the applicability of proper prototypes and how easy is to evaluate prototype intelligent interfaces without developing all the functionality? To the next, we are discussing advantage and disadvantages of various kinds of prototypes for research purpose.

6.4.2.1 Selection of prototype

Kespohl and Szwillus (1996) present the KAP (Kespohl application prototype) tool for prototyping user interfaces of 'technical devices' such as videocassette recorders, CD players, alarm clocks, answering machines, telephones etc. They claim that KAP has significant advantages over programming based environments since the KAP user needs to know only about states and rule-based state transitions.

Virzi *et al.* (1996) compared the usability problems uncovered using low- and high-fidelity prototypes. They concluded that the use of low-fidelity prototypes could be effective throughout the product development cycle and not just during the early phases of design.

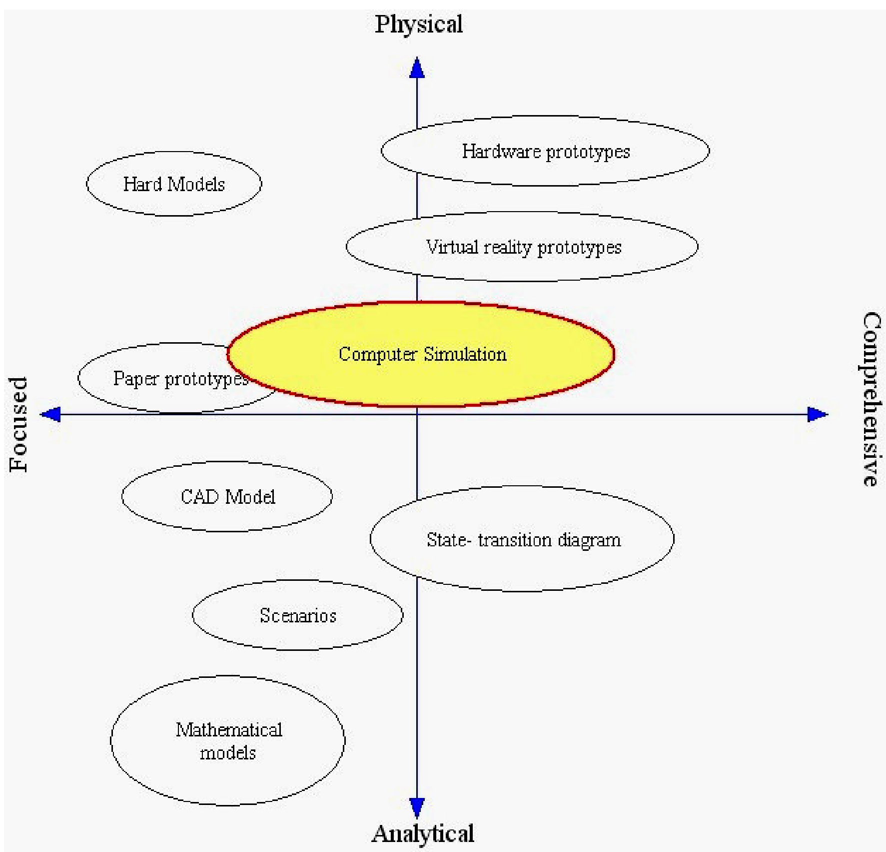

Figure 6-3 Prototyping method comparison and suitability

Ruuska *et al.*(2000) reported on the development of a prototyping environment for telephone user interfaces. At Siemens, they have implemented a user interface prototyping environment for designers and product managers with little or no experience with programming or knowledge of the internal software architecture of the actual phone.

Ulrich and Eppinger (1995) presented a rough ordering of the prototyping method using the physical/analytical vs. comprehensive/focused dimensions as shown in figure 6-3.

According to Ruuska *et al.*(2000) the most important reason for building computer simulation prototypes (e.g. PDA) of user interface is that the user interface is becoming so complicated that it is difficult to envision how usable a new interface design or modification will be without simulated user interface. We found computer simulation method most appropriate for our research purpose. This method is focused to our aim and comprehensive enough to test all the variables needed for them. It gives an excellent physical appearance to the user and due to its recording feature serves good for analytical purpose.

6.4.2.4 Simulation detail

Prototype for simulation was realised by multiple iteration to check the content and for their usability. It was insured to have same content and task in both the simulation. Before designing tasks have been defined and accordingly programmed. To model the contents of user interface simplest modelling technique of paper and post –it-notes have been used. Modelling was particularly inspired by the work of Holtzblatt (1993), Beyer and Holtzblatt (1998) that is what known as "work environment" model as part of contextual inquiry[68]. We have primarily focused that the more realistic the prototype simulation is the more likely users are to see it as the actual user interface. As the whole concept was implemented in full functional simulation, it is obviously treated as an active prototype. Eventually it was able to demonstrate real behaviour and functional capability.

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[68] Contextual inquiry is an approach to requirement gathering and definition that grew out of work stated at Digital Equipment Corporation. Although there has been some dispute over early history and appropriate credit, there is little doubt that its most visible and active proponents have been Karen Holzblatt and huge Beyer.

Prototype was prepared using “Flash Programming” and was realized by using “Macromedia Captivate” for running the simulation. Two simulations were done: one for linear type of menu and other for non-linear menu. Sample pictures of both types are illustrated in figure 6-4.

Figure 6-4 Simulated non-linear and linear menu

6.4.3 *Laboratory test and data collection*

An ad-hoc laboratory was established in university campus with required simulation tool and furniture. Users have been invited with prior invitation to take part in test. The laboratory set-up was meeting the essential requirement for unbiased observation and data recording. We produced three different tasks in two sets to evaluate the complexity of menu in use. These tasks were all designed to be carried out on a simulated PDA on a desktop screen. Each test was quite simple and we estimated that the whole test would be carried out in less than sixty minutes. It was also a tool for us to see what information we missed when the mobile device was used in an artificial environment.

6.4.4 *Floor plans and test environment*

A 5 X 3 m room was equipped with 2 tables and 2 chairs, utilised for setting up test lab. Tables were put in L- shape as shown in figure 6-5.

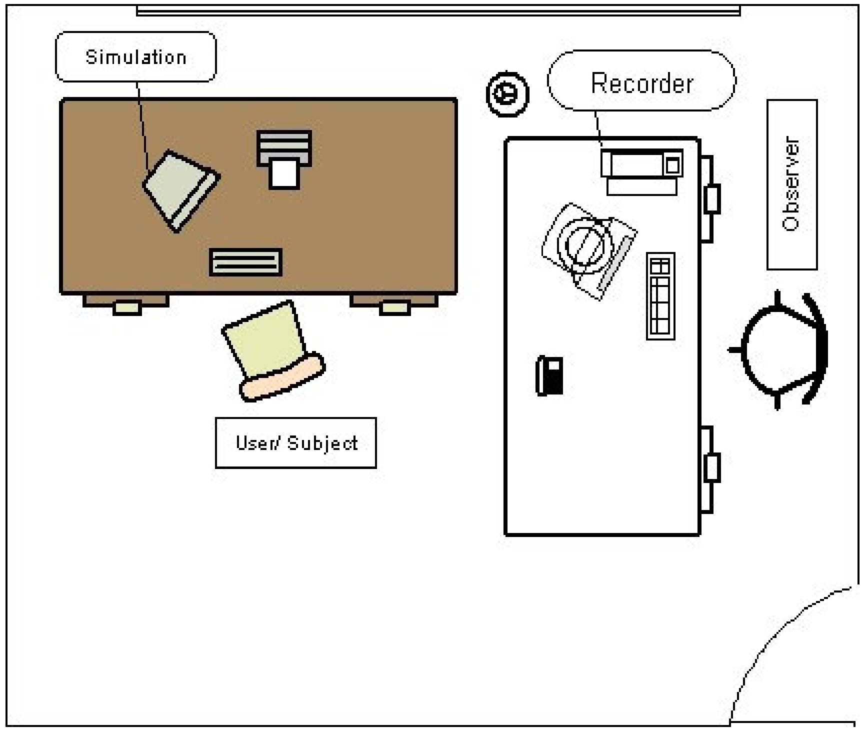

Figure 6-5 Floor plan and experiment setting

A 17-inch monitor had been used as simulation screen; a notebook of high performance configuration (Pentium IV, 2.4 GHz, 80 GB, 512 RAM) was used to execute the simulation and simultaneously to record the user's activity while performing the task into simulated application.

Subjects were asked to sit facing simulation screen while observer was sitting on other side of the table. Subjects were provided with introduction script and tasks followed by questionnaire. A short introduction of 10 min. has been given by researcher to be familiarised by the simulation detail and procedure to get ready with test.

6.4.5 Test cases, task scenarios and protocol

There were three test cases in whole experiment. The test cases were prepared while keeping scenario of a routine task performed in a small industrial technicians (plumbers, painters, welders, and car mechanics were the most common test persons) firms in mind. In first test case, it was asked to create an assignment detail of new customer, second test case was to edit/change the date of assignment and third test case was to create and store an employee database. These tasks were extracted from a routine work in small-scale industrial application dealing with customers quarry. The idea was to provide a feeling of working at professional situation. Observation and recording objectives were also added in the aims to defining these tasks accordingly, which are as described below.

Task 1 (creation of an assignment detail for new customer) was prepared in such a way to see, how user starts using both menu art and proceed to next required steps. The content or items present on the screen were same. We have used the same phrase in both cases to avoid bias between these two menus (e.g. create, new, assignment, date etc.). Creation of new assignment task facilitated us important information about a general understanding on the structure of menu art. There was only one ideal path to complete the task i.e. successful creation of assignment. While making a single error, users were then forced to correct it through different option (e.g. repeating the process again, trying out clicking other objects on the screen etc.) The entire deviated paths were precisely recorded.

Task2 (change/editing assignment details) has been given to user to check generic understanding of the user to change or edit a detail, that he has shortly before entered. If a particular kind of menu structure suited to his perception, he should be easily done without much problem. It facilitated us information about structural understanding of menu by different subjects.

Task3 (creating a new database) has been given to know the learnability of menu pattern; it was believed that after using particular menu art twice, users are able to follow the working paths of menu. The entire three tasks were intended and designed in such way to work with different depth level of menu. The users were required to use these depth levels for successful completion of task.

A protocol of 20 minutes (10 minutes brief description about purpose, background and test proceedings additionally 10 minutes for trial with simulation) was done. A paper based short help and introduction was supplied to every subjects.

The experiment was performed at two places. Non-technicians were called in university campus whereas technicians performed at the ‘computer and automation lab’ of chamber of commerce and industry Flensburg (IHK- Flensburg).

6.4.6 *Subject's profile*

There were 53 subjects (26 non-technician and 27 technicians) non-technicians were coming from different section from society of different age group [below 20, 21-35, 36-50, 51-65, above 65] and sex. Nearly half of them (14) were also studying at University of Flensburg. All of the technicians were from Flensburg region; they comprised diversified streams of plumbing, welding, painting, automobile etc. A detailed subject profile of all the 53 participants is shown in Appendix D.

Out of 53 subjects, nearly 65 % (N=34, 24 technicians, 10 non-technicians) belongs to the age group of 21-35. The next largest group of nearly 21% was belonging to age group 36-50 (N= 11, 10 technicians, 1 non-technician). 7.5 % (N=4, all of them technician) subjects were below 20, whereas only 3 subjects were belonging to age group of 51-65 (all of them technicians. Only one subject was 65 years old non-technician.

There were 36 % (N= 19) female and 64 % (N=24) male. Out of 53, around 51% (N=27) technicians and 49% (N=26) were non-technicians. There were 4 subjects below the age of 20 years; all of them were male technician doing their apprentice training. While selecting the subject professional background was fixed at first-degree priority and then gender and finally the age group. Professional distribution meets the criteria excellently with nearly equal ratio, gendered distribution was satisfactory and we found participants at least from each age group (except only one subject belonging to above 65 age group). Therefore, a balanced subject profile has contributed in the research study.

6.4.7 *Data recording*

Three level data collection is being done for the experiment.

a) Users rating: every part of questionnaire is followed by assessment sheet. Users were asked to fill up the sheet by giving the rating from 1 to 5 (1= fully agree, 5= not at all). (see appendix B)

b) System: Automated recording is done by simulation software while users perform the test. Each actions is being recorded in captivate movie format. Later they can be transformed in executable file to view and analyse them. (See appendix C for sample). Time, menu selection, clicks and typing events is being exclusively highlighted in output.

c) Observer: while conducting the test, observer takes notes of unique events done by users on a separate sheet for the purpose of future analysis.

6.4.8 *Decision logic in hypothesis testing*

6.4.8.1 Decision making in first hypothesis

The following logical schemes (figure 6-6) have been adopted to make decision on our hypothesis. Null hypothesis has been formulated and tested in three parts. We have assumed that complexity of interface cannot be said decreased or increased if satisfaction rating (SS_L & SS_{NL}), error committed (E_L & E_{NL}) and time taken (T_L & T_{NL}) by users altogether remain unchanged.

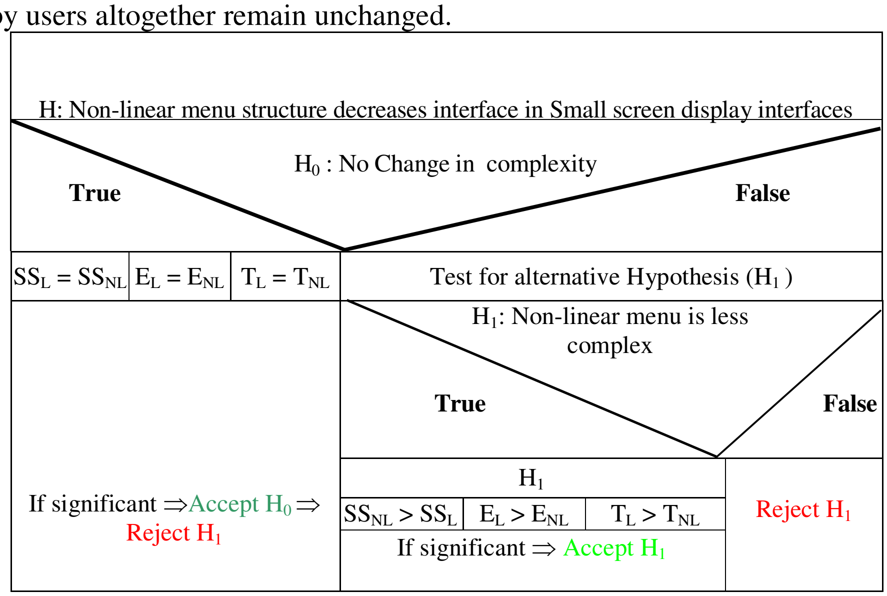

Figure 6-6 Decision making in first hypothesis

Rejecting null hypothesis leads to test for alternative hypothesis in which we expect results inclined towards our main hypothesis. If any part of alternative hypothesis fails to meet acceptance condition, we will reject H_1. If both null and alternative hypothesis falls into rejection area, state of no significant conclusion will be resumed.

6.4.8.2 Decision making in second hypothesis

Second hypothesis is also tested with similar procedure adopted for H_1.

Parameters that have been statistically evaluated are efficiency (η) and productiveness (ρ) at different depth (3rd level & 4th level) of menu.

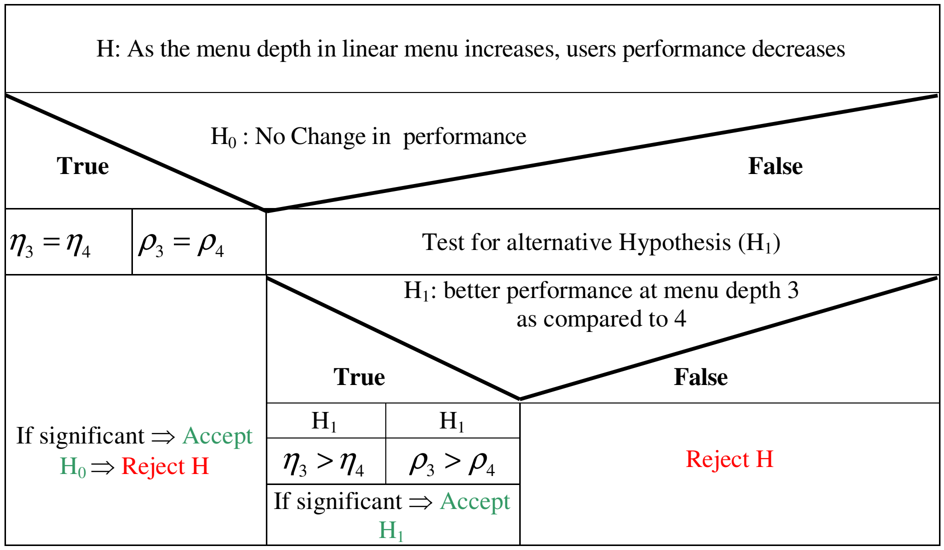

Figure 6-7 Decision making in second hypothesis

Initially we assumed that performance remains same at different level of menu. This assumption build basis for our null hypothesis. As shown in figure 6.7, we accept our null hypothesis if both efficiency and productiveness remains significantly unchanged otherwise test for alternative hypothesis is carried out.

Our alternative hypothesis is in fact confirming main hypothesis, in which we anticipate that efficiency and productiveness both are significantly better at lower depth of linear menu. Similar to previous hypothesis, if both null and alternative hypothesis falls into rejection area, state of no significant conclusion will be resumed.

Chapter 7

Evaluation and result explanation

While conducting research upon interface for small screen devices it has been found that it is critical and difficult due to lack of research material availability. The assessment and comparison of interfaces with linear and non-linear menu is a necessary part of the current study. The best way to do this is through an empirical evaluation. Unfortunately, such evaluations are time-consuming and complicated. Careful planning and execution is required while undertaking such an evaluation, as an abundance of confounding factors exists that could negatively affect its repeatability and validity.

To control confounding factors, empirical evaluations place participants in constrained, artificial environments. This allows the behaviour or behaviours of interest to be isolated and thus accurately measured. To ensure the validity of an evaluation, however, it has to be designed to be as representative of actual user behaviour as possible (Mackenzie & Soukoreff, 2002). Mackenzie & Soukoreff (2002) suggest this need not result in a trade-off between accuracy and relevancy. Instead, evaluations should be designed to maximize both relevancy and accuracy.

Many sources of empirical data can be used to evaluate an interface (e.g., time to learn, time to perform benchmark tasks, number of errors on benchmark tasks, answers on questionnaires, comments made in verbal protocols). Ebling and John (2000) examines the contributions of different sources of data collected during an empirical test and found in such a test, many sources of empirical data can be used in the evaluation. These sources include quantitative data (such as learning time, number of errors, number of steps required) and qualitative data (such as questionnaires and verbal protocol). Study performed in PDA many researchers (Detmar & James, 1989); (Ives *et al.*, 1983) preferred accuracy (error analysis), efficiency (time analysis) and preference (satisfaction analysis).

In this chapter, we are evaluating the test performed in a lab as mentioned in previous chapter. Before forwarding to the analysis and evaluation, we want to explain statistical tests, which we have used in testing our hypothesis.

One of the most common experimental designs is the "pre-post" design. A study of this type often consists of two measurements taken on the same subject, one before and one after the introduction of a treatment or a stimulus. The basic idea is simple. If the treatment had no effect, the average difference between the measurements is equal to 0 and the null hypothesis holds. On the other hand, if the treatment did have an effect (intended or unintended!), the average difference is not '0' and the null hypothesis is rejected. Paired sample t –test is one strong and robust test to determine significant difference. The paired-samples t-test procedure is used here to test the hypothesis of no difference between two variables. The data consist of two measurements is taken on the same subjects. Assumptions to use this test are that observations for each pair made under the same conditions and the mean differences are normally distributed.

If the sample is normally distributed, we will adopt paired sample t-test to determine significant difference between the groups otherwise we will use non-parametric procedure like Wilcoxon-signed rank test. It is called nonparametric because it makes no assumptions about the parameters of a distribution, nor does it assume that any particular distribution is being used. The Wilcoxon signed-ranks method tests the null hypothesis that the two related medians are the same. This test allows comparing a single median against a known value or **paired medians from the same** (or matched) **sample**. It compares the distributions of two related variables. The Wilcoxon signed-rank test considers information about both the sign of the differences and the magnitude of the differences between pairs. Although no particular distributions are assumed for the two variables, the population distribution of the paired differences is assumed symmetric.

To test the normal distribution we are using one-sample kolmogorov-smirnov procedure. This test is based on the null hypothesis that a sample comes from a particular distribution (in our case normal distribution). It does this by finding the largest difference (in absolute value) between two cumulative distribution functions (A cumulative distribution function returns the probability that a variate of a given distribution falls below a given value for continuous functions and at or below a given value for discrete functions) one computed directly from the data; the other, from mathematical theory. (Siegel and Castellan, 1988)

The kolmogorov-smirnov Z is computed from the largest difference (in absolute value) between the observed and theoretical cumulative distribution functions. This goodness-of-fit test tests whether the observations could reasonably have come from the specified distribution. This procedure estimates the parameters from the sample. The sample mean and sample standard deviation are the parameters for a normal distribution. A larger value of Z (> .05) determines that sample is normally distributed. (Siegel and Castellan, 1988)

the whole statistical test decision may be summarised as , first we will determine normality of distribution using 1-sample Kolmogorov-smirnov test, if sample is normally distributed we will use paired sample t-test to determine significance in difference. If sample is not normally distributed, we will use non-parametric technique like Wilcoxon- signed rank test to determine the significance of difference.

Alpha (α) adjustment: In our hypothesis testing, we have three variables i.e. satisfaction score, time and error to test. In such a case of repetitive measurement, there is higher risk of inducting built-in alpha error. This is a common problem of multiple testing. If one submits each individual variable to a test, alpha error for the whole family of tests becomes very large. That means, significance level of alpha=5% for each individual comparison consists of probability that any of these three comparisons coincidentally leads to a significant result. Alpha error probability, for the comparison of whole family (all the three comparison) because of separate individual comparison, will be

$$\boxed{\alpha_F = 1-(1-\alpha_V)^K}$$

In our case then

$$\alpha_F = 1-(1-0.05)^3 = 0.1426$$

That is then approximately 15% instead of 5 %. To avoid this risk of higher alpha error (15%), the significance level of individual comparison to be increased in such a way that significance level of family comparison equals the desired alpha error probability (i.e. 5%). This can be achieved by

$$\boxed{\alpha_V = 1-(1-\alpha_F)^{\frac{1}{K}}}$$

Adjusted $\alpha_V = 1-(1-0.05)^{\frac{1}{3}}$ = 0.0169

The above method of alpha adjustment will be adopted in our hypothesis testing. After adjusting, the alpha we have found that significance level of alpha for individual comparison will be 1.69 % instead of 5 %.

7.1 Test of hypothesis (H)

Non-linear menu structure decreases interface complexity in Small screen display interfaces

To assess the change in complexity of menu we have defined the variables under which we are testing our hypothesis in chapter 6. Recalling once again that, in our study we have established the concept of MTO (man- technology- organisation) from the start.

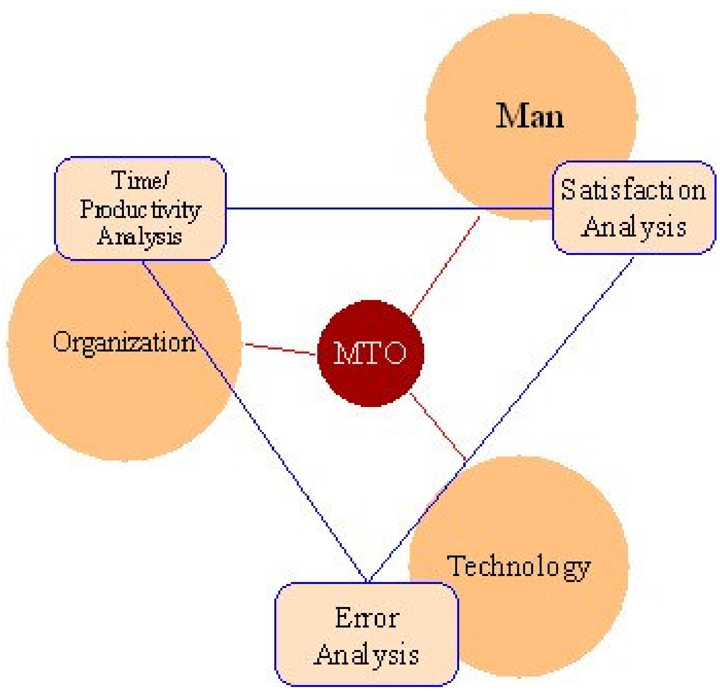

Figure 7-1 MTO proposition in hypothesis testing

At this stage of hypothesis testing, we are critically examining these three to see what effect they are causing to our null hypothesis. As demonstrated in figure 7-1, satisfaction analysis is prime consideration under human aspect. Error analysis put together with technology as errors are supposed to make on. Time and productivity analysis is done on organisation. Age and gender is to be considered under human aspect, as technological tool we are considering both type of menu whereas profession is what we are considering as organisational input.

In our test case, technician and students are two groups.

Variables:

SS_L and SS_{NL}: satisfaction score of linear and non-linear menu,
E_L and E_{NL}: error committed to achieve the task in linear and non-linear menu, whereas
T_L and T_{NL}: time taken to complete the task in linear and non-linear menu respectively

For the ease of hypothesis testing let, we first formulate null and alternative hypothesis. Our null hypothesis will be

7.1.1 *Null hypothesis (H_0) for first hypothesis*

There is no effect or no change in the Interface complexity of linear and non- linear menu.

Involving parameters and contributing variables our hypothesis can be precisely formulated in the following way:

H_o:
- There is no difference in the mean satisfaction score of linear and non-linear menu.[$SS_L = SS_{NL}$]
- There is no difference between mean error committed in linear and non-linear menu [$E_L = E_{NL}$]
- There is no change in mean time taken to complete the task in linear and non-linear [$T_L = T_{NL}$]

7.1.1.1 Acceptance condition of null hypothesis

We accept our null hypothesis if at lease two of above conditions are true otherwise; we will reject and test for alternative hypothesis.

7.1.1.2 Satisfaction score analysis for null hypothesis (H_{0-1})

Users completed 'ease of use' ratings on a scale of 1 to 5 (1 = extreemly easy, 5 = extreemly difficult) after every task. Participants completed a questionnaire at the end of each taskand an overall preference questionnaire at the completion of task specific to menu type.

7.1.1.2.1 Test for normal distribution

1-sample kolmogorov-smirnov test was performed to test if the data are normally distributed. Test statistics shown in Table 7-1 depict the kolmogorov-smirnov test, which compares an observed cumulative distribution function to a theoretical cumulative distribution. In this case, the ***normal distribution*** is selected. Normal parameters (mean and std. deviation) of the theoretical distribution are estimated from the observed data. Total score is weighted score of all the three tasks and collected based on questionnaire. It has been found that mean satisfaction score of linear menu 106.91 (N = 53, S.D = 18.492) is considerably lower than satisfaction score of non-linear menu 126.42 (N= 53, S.D = 15.742). Absolute indicates the largest absolute difference (0.102 and 0.194) between the theoretical cumulative distribution and the observed cumulative distribution function. Large significance value ($p > .05$) in case of linear menu indicates that the observed distribution corresponds to the normal distribution.

Kolmogorov-Smirnov Test for normal distrubution

		Satisfaction score of Linear Menu	Satisfaction score of Non-Linear menu
N		53	53
Normal Parameters [a,b]	Mean	106.91	126.42
	Std. Deviation	18.492	15.742
Most Extreme Differences	Absolute	.102	.194
	Positive	.079	.194
	Negative	-.102	-.182
Kolmogorov-Smirnov Z		.742	1.413
Asymp. Sig. (2-tailed)		.640	.037

a. Test distribution is Normal.

b. Calculated from data.

Table 7.1 Test of normality on satisfaction score data

Based on the test statistics, we can conclude that observed satisfaction score data in case of linear menu are normally distributed. In contrast, the significance value in case of non-linear menu is only slightly smaller than 0.05 (0.037) hence we cannot conclude if the data has normal distribution.

Since data observed in one of the case is not normally distributed, we will apply parametric and non-parametric technique to analyse the result.

7.1.1.2.2 Test of significance in satisfaction score analysis:

A paired sample t-test has been performed to testify if the difference of score in two observed sample is significant enough.

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	**98.13% Confidence interval of the Difference** Lower	Upper			
Satisfaction score of non-linear menu - Satisfaction score of Linear Menu	19.51	18.799	2.582	13.24	25.78	***7.555***	52	***.000***

Table 7.2 Paired sample t –test for satisfaction score analysis

The paired sample t-test of satisfaction score (Table 7.2) shows significant difference (t_{52}= -7.555, p<0.0169) between linear and non-linear menu. As one category does not have normal distribution, we tested significance again by using non-parametric technique.

Test Statistics[b]

	Satisafction score of Non-Linear menu - Satisfaction score of Linear Menu
Z	-5.321[a]
Asymp. Sig. (2-tailed)	.000

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Table 7.3 Wilcoxon Signed Ranks test for significance

Wilcoxon Signed ranks test was performed and test detects (Table 7.3) differences in the distributions of two related variables (Z = -5.321, p< 0.0169) which indicates the distribution of satisfaction score in linear menu is different from non-linear menu.

Result review:

1. Observed satisfaction score data for linear menu clearly indicates that data are normally distributed but it cannot be concluded in case of non-linear menu if they are normally distributed.

2. Parametric test (paired sample t- test) points out that linear menu and non-linear menu are significantly different **($SS_L \neq SS_{NL}$)**

3. Wilcoxon Signed ranks test (non- parametric) also reveal that distribution of satisfaction score in linear menu is different from non-linear menu **($SS_L \neq SS_{NL}$).**

7.1.1.3 Error analysis for null hypothesis ($H_{0\text{-}2}$)

7.1.1.3.1 Test for normal distribution

Kolmogorov-Smirnov test was performed again to test if the data are normally distributed. Test statistics shown in Table 7.4 depicts that mean error in case of linear menu 16.66 (N = 53, S.D = 11.61) is higher than mean error committed in case of non-linear menu 3.91 (N= 53, S.D = 5.35).

Kolmogorov-Smirnov Test for normal distribution

		Error made in linear menu	Error made in non-linear menu
N		53	53
Normal Parameters [a,b]	Mean	16.66	3.91
	Std. Deviation	11.616	5.354
Most Extreme Differences	Absolute	.142	.233
	Positive	.142	.229
	Negative	-.089	-.233
Kolmogorov-Smirnov Z		1.032	1.695
Asymp. Sig. (2-tailed)		.237	.006

a. Test distribution is Normal.

b. Calculated from data.

Table 7.4 Test of normality for error analysis

Largest absolute difference found 0.142 and 0.233 for linear and non-linear (table 7-4) respectively between the theoretical cumulative distribution and the observed cumulative distribution function. Large significance value >.05 in case of linear menu indicates that mean error in case of linear menu has normal distribution. Nevertheless in case of non-linear significance value (0.006) is fairly smaller than 0.05, and can not be concluded, as if, it has normal distribution. Since one group is not confirmed normally distributed we will apply both parametric and non-parametric techniques to test the significance.

7.1.1.3.2 Test of significance in error analysis

The paired sample t-test of mean error (Table 7.5) showed significant difference (t_{52}= 7.523, $p < 0.0169$) between linear and non-linear menu.

	Paired Differences					t	df	Sig. (2-tailed)
				98.31% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Error made in linear menu - Error made in non-linear menu	12.75	12.343	1.695	8.57	16.94	*7.523*	52	*.000*

Table 7.5 Significance test for error analysis

As 98.31 % confidence interval for the mean difference does not contain zero, this also indicates that the difference is significant.

Test Statistics [b]

	Error made in non-linear menu - Error made in linear menu
Z	-5.402[a]
Asymp. Sig. (2-tailed)	.000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Table 7.6 Wilcoxon Signed Ranks test for significance difference of error

Wilcoxon Signed ranks test also spotted differences in the distributions of linear and non-linear variables ($Z = -5.402$, $p< 0.0169$), which indicates the distribution of error committed in linear menu is different from non-linear menu.

Result review

1. Observed Error data for linear menu indicates that data are normally distributed but it cannot be concluded in case of non-linear menu whether it has normal distribution.

2. Parametric test (paired sample t- test) indicates that mean error rate in linear menu and non-linear menu are significantly different ($E_L \neq E_{NL}$).

3. A non-parametric technique Wilcoxon Signed ranks test also revealed differences in the distributions of linear and non-linear variables ($Z = -5.402$, $p< 0.0169$) which indicates the distribution of error committed in linear menu is significantly different than of non-linear menu ($E_L \neq E_{NL}$).

7.1.1.4 Time analysis for null hypothesis (H_{0-3})

7.1.1.4.1 Test for normal distribution

Kolmogorov-Smirnov test was done to test the data to determine normality of distribution. Test statistics shown in Table 7-7 depict The Kolmogorov-Smirnov Test that compares observed cumulative distribution function to an inbuilt theoretical cumulative distribution (in this case, the normal distribution is assumed).

Kolmogorov-Smirnov Test for normal distribution

		Time taken in linear menu	Time taken in non-linear menu
N		53	53
Normal Parameters [a,b]	Mean	239.402	129.828
	Std. Deviation	67.8844	29.6758
Most Extreme Differences	Absolute	.106	.166
	Positive	.106	.166
	Negative	-.066	-.074
Kolmogorov-Smirnov Z		.775	1.207
Asymp. Sig. (2-tailed)		.585	.109

a. Test distribution is Normal.

b. Calculated from data.

Table 7.7 Kolmogorov-Smirnov test for time distribution

For the ease of understanding, we want to make it clear that Kolmogorov-Smirnov test is based on the null hypothesis of being data not normally distributed. Henceforth higher significance value (>0.05) of the test confirms the data to be normally distributed. Earlier in this chapter and further, we will use this test to testify observed data for normal distribution. Parameters (mean and std. deviation) of the theoretical distribution are estimated from the observed data. Total time is the sum of time taken to complete the individual tasks that was simultaneously recorded by the simulation software.

It has been found that mean total time taken to complete the tasks in linear menu 239.40 s (N=53, SD=67.88) is noticeably higher than time taken to complete the tasks in non-linear menu 129.82s (N=53, SD=29.67). In this case, the significance value for linear (Z_{53}= 0.77, p= 0.585) and non-linear menu (Z_{53}=1.207, p=0.109) exceeds .05. Thus, the distribution of time in both types of menu resembles a normal distribution. Procedures, which assume normality, can be employed for analysing these data.

7.1.1.4.2 Test of significance for time analysis

A paired sample t-test has been executed to see if the difference of time taken in two observed sample is significant enough.

	Paired Differences					t	df	Sig. (2-tailed)
				98.31% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Time taken in linear menu - Time taken in non-linear menu	109.574	67.6856	9.2973	86.625	132.522	***11.785***	52	***.000***

Table 7.8 t-test for time taken to complete the task in linear and non-linear menu

The paired sample t-test of time taken to finish the task (table 7-8) showed significant difference (t_{52}= 11.785, $p < 0.0169$) between linear and non-linear menu. It can be seen that 98.31% confidence interval of the difference does not contains null value. It also indicates that difference is significant.

7.1.1.5 Decision on null hypothesis (H_0)

Initially, we have established three basic condition to accept our null hypothesis- namely if there is no change in degree of satisfaction, if there is no change in error making and if there is no change in time taken. We have carefully analysed and statistically tested all of the above-mentioned condition in previous paragraphs. None of three meets up the requirement to accept our null hypothesis, so we are rejecting H_o and will test for our alternative hypothesis to validate our hypothesis made before research in following paragraphs.

7.1.2 *Alternative hypothesis H_1 for first hypothesis*

H_1 : There is change in the Interface complexity of linear and non-linear menu.

Let us formulate the test conditions as follows:

H_1 {

Mean satisfaction score of non-linear menu is more than linear menu ($SS_{NL} > SS_L$)

Mean error committed in non-linear menu is less than linear menu ($E_{NL} < E_L$)

Mean time taken to complete the task in non-linear menu is less than linear menu ($T_{NL} < T_L$)

7.1.2.1 Satisfaction score analysis for alternate hypothesis (H_1)

Mean satisfaction score of non-linear menu is more than linear menu ($SS_{NL} > SS_L$)

From the descriptive statistics, it has been found that mean satisfaction score of linear menu is considerably low (M= 106.9, S.D=18.4) in comparison to (M= 126.4, S.D= 15.7) non-linear menu.

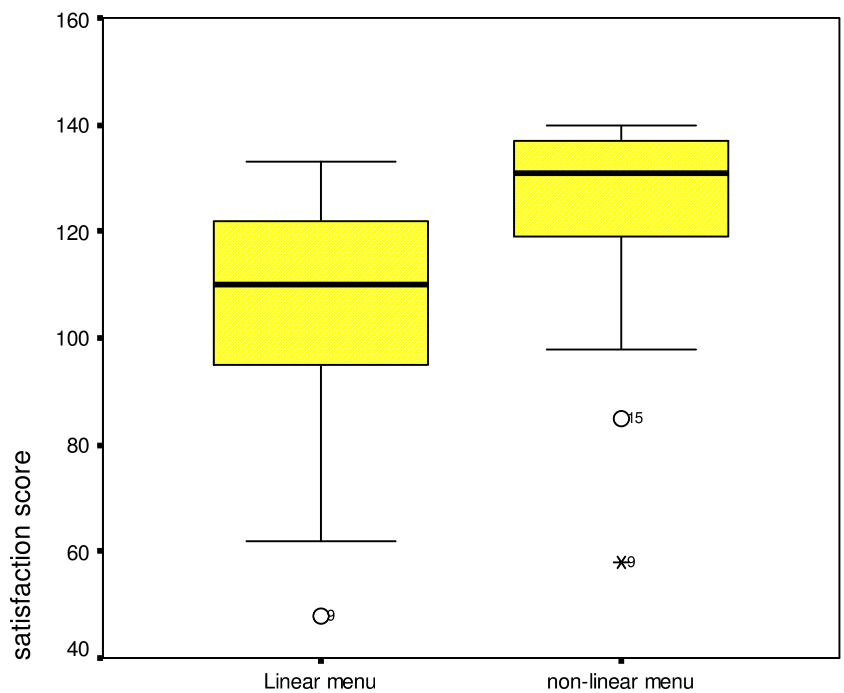

Figure 7-2 Satisfaction score comparison

As shown in figure 7-2, in case of linear menu, satisfaction score ranges between 65 and 130 (mostly 90 to 120) where as in case of non-linear menu it ranges between 90 and 140 (mostly 120 to 135). One subject [S9] found outliers in linear menu, interestingly the same subject found extreme in case of non-linear menu. Statistically significant score given to linear menu is found as less as 65 out of 140, where as it is quite high in case of non-linear menu (90/140). We want to mention it again; smaller the satisfaction score entails the higher complexity of using menu. Test also confer us result that 75 % subjects has given rating below 121.23, while there are only 25 % subjects who rated non-linear menu below 119.17. Hence, we can conclude **$SS_L < SS_{NL}$.**

Let us examine task wise satisfaction score to understand the amount of complexity from the user's point of view and feedback. As the users were asked to rate the complexity of tasks divided into three parts (each part with 30 points).

7.1.2.1.1 Task 1: subject Vs satisfaction score

For the task 1, users have given mean satisfaction score of 27.1 to non-linear menu whereas 19.9 to linear menu (Table 7-9).

Task (max. score)	Linear menu	Non-linear menu
Task1 (30)	19.9	27.1
Task2 (30)	23.0	26.5
Task3 (30)	24.8	26.6
Overall (140)	**106.9**	**126.4**

Table 7.9 Mean satisfaction score for both menus

Distribution of score for both menus has been sketched for each subject and can be seen in figure 7.3. From the scatter plot, it is clear that most of the users found non-linear menu much simpler.

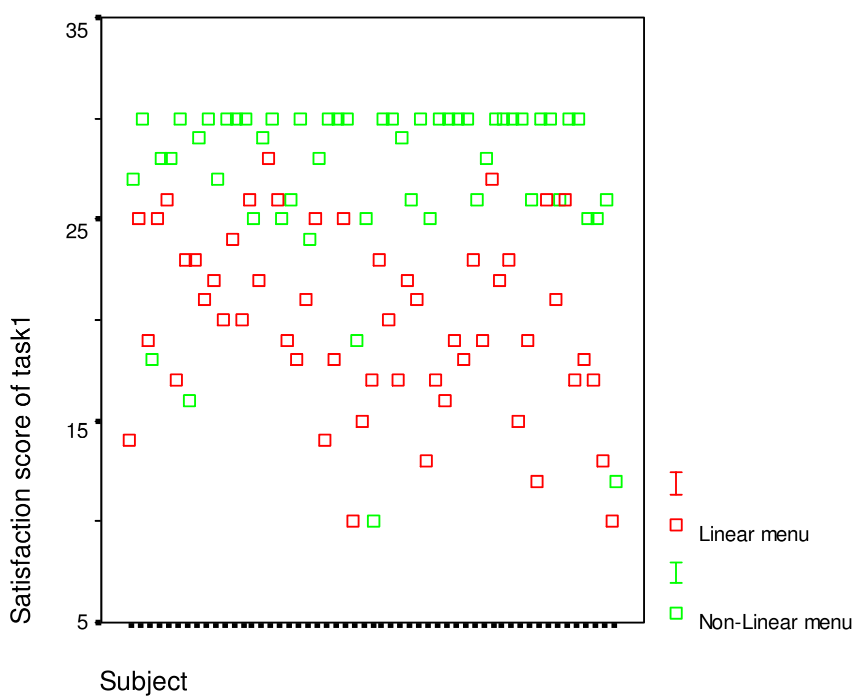

Figure 7-3 Distribution of satisfaction score for task 1

There were 26 users, who have given full points to the non-linear menu (green squares at score point of 30 in figure 7-3); however, no user has given full points to linear menu.

7.1.2.1.2 Task 2: subject Vs satisfaction score

The mean value of satisfaction score (N =53, SS_L=23, SS_{NL}= 26.5), in case of task 2, indicates that user rating is greater for non-linear menu as compared to linear menu. Distribution plot for task 2 in figure 7-4 shows that maximum number of users rating for linear menu lying below to non-linear menu.

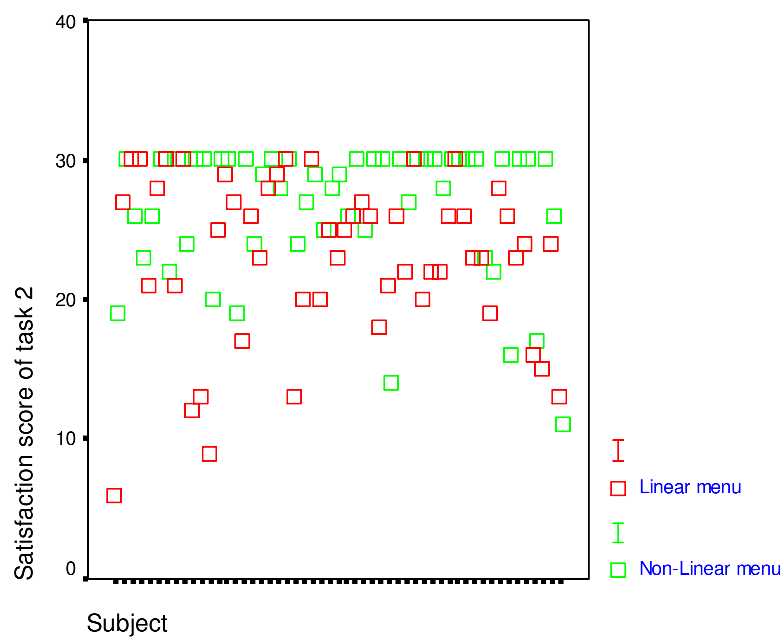

Figure 7-4 Distribution of satisfaction score in task 2

24 users have given highest rating to non-linear menu. It was three times higher against eight users, who have given highest rating to linear menu.

7.1.2.1.3 Task 3: subject Vs satisfaction score

Mean satisfaction score for linear menu (N=53, SS_L=24.8) and for non-linear menu (N=53, SS_{NL}= 26.6) was observed while users performed on task 3. Score for non-linear menu is still higher than linear menu, which indicates users liking more towards non-linear menu rather than linear menu. Distribution plot shown in figure 7.5 still indicates that subjects who are rating for non-linear menu, is denser towards highest score. Twelve users have given highest rating to linear menu is nearly half as compared to 23 users who have given highest rating to non-linear menu.

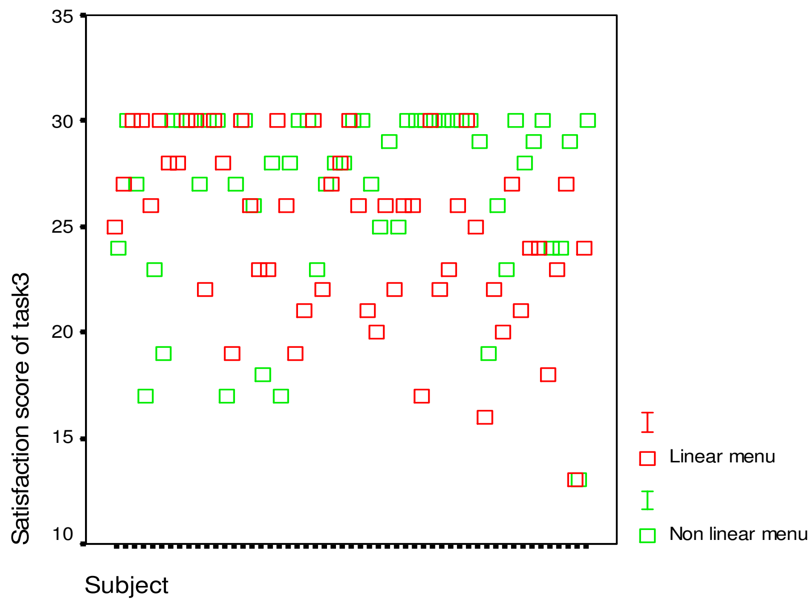

Figure 7-5 Distribution of satisfaction score in task 3

We have calculated weighted satisfaction score of all the three tasks added to principle score (in-general feedback) and plotted against subject as shown in Figure 7.6. Analysis of all the three tasks and rating given by users indicates that, though increasing no. of users given more rating to linear menu (Task 1: 0, Task 2: 8, Task 3: 12) but they are still lying below to non-linear menu (Task 1: 26, Task 2: 24, Task 3: 23).

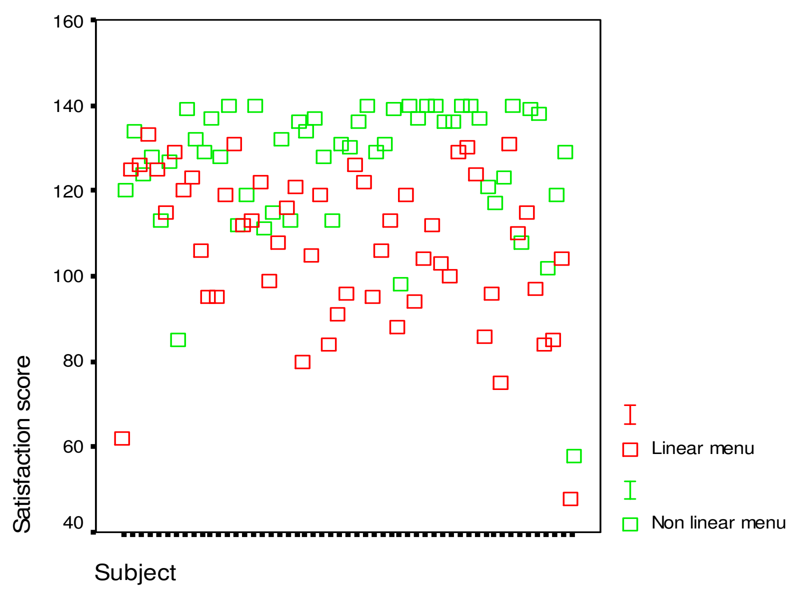

Figure 7-6 Distribution of total score

Possible cause of increasing rating in case of linear menu may be user's learnability with the type of menu. It may be possible that frequent use of linear menu facilitates users more ease to work with. The important thing to remark here is non-linear menu structure provides sustained satisfaction and in every case, rating is higher independent of frequency of use.

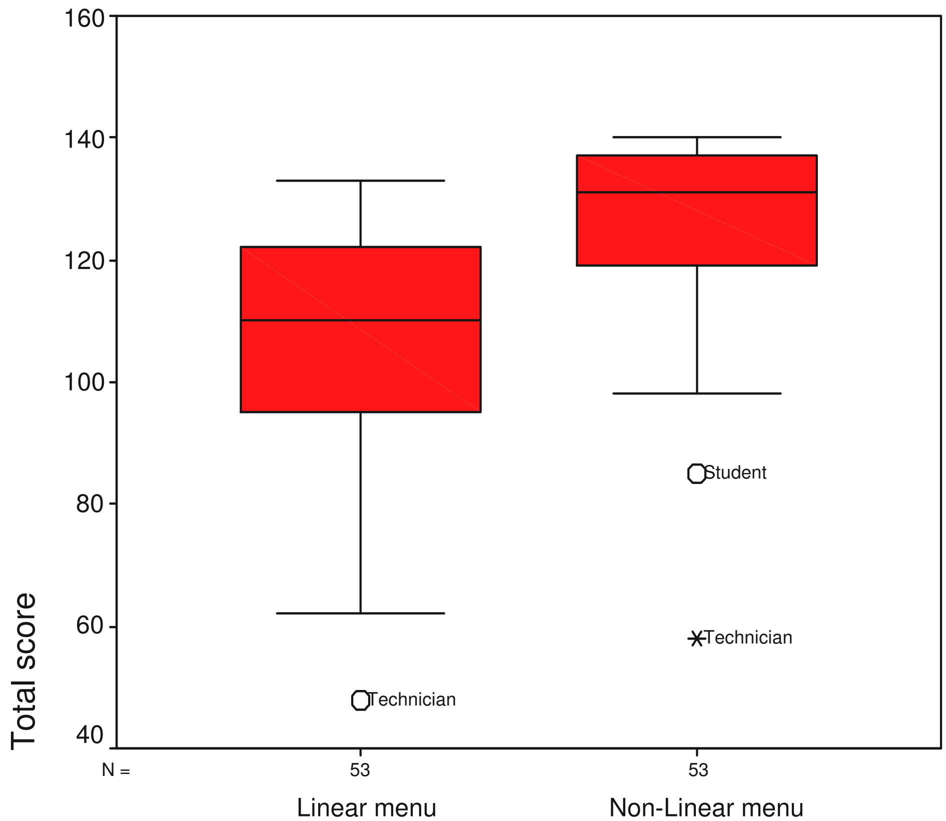

Figure 7-7 Box plot of total score Vs menu type

We have drawn a box plot of mean value of total score as shown in figure7-7, they indicates clearly in both that total score for non-linear of most users have more rating as compared to linear menu.

As shown in Box plot, total score for linear menu is mostly distributed between 90 and 120 (N= 53, Maximum =133, Distribution Range: 60-135) whereas in case of non-linear menu it is 120-135 (N= 53, Maximum=140, Distribution Range: 90-140). Test statistics for linear menu (N=53, Mean= 106.9, SD= 18.49, Min= 43, Max= 133) validates once again our hypothesis that non-linear menu (N=53, Mean= 126.4, SD= 15.74, Min= 58, Max= 140) decreasing interface complexity from the user's satisfaction point of view.

7.1.2.2 Analysis of user's satisfaction under MTO aspect:

In the following paragraph, we discuss the effect of parameters (Age, sex, and profession) to our variables i.e. linear and non-linear menus. We have already discussed the relevancy of MTO (see chapter 1 & Chapter 3). In the beginning of this chapter, we have established some of test parameters to utilise for measurement for the ease to test our hypothesis. In coming paragraph, we will examine these in detail.

7.1.2.2.1 Profession Vs satisfaction score

In our experiment there were two groups comprising 27 technicians and 26 students. We found both the groups were more satisfied with non-linear menu. Students have given average rating of 111.3 (N=26, SD= 15.52), whereas technicians 102.5 (N=27, SD= 20.31) to linear menu. There is a minor difference between the average ratings.

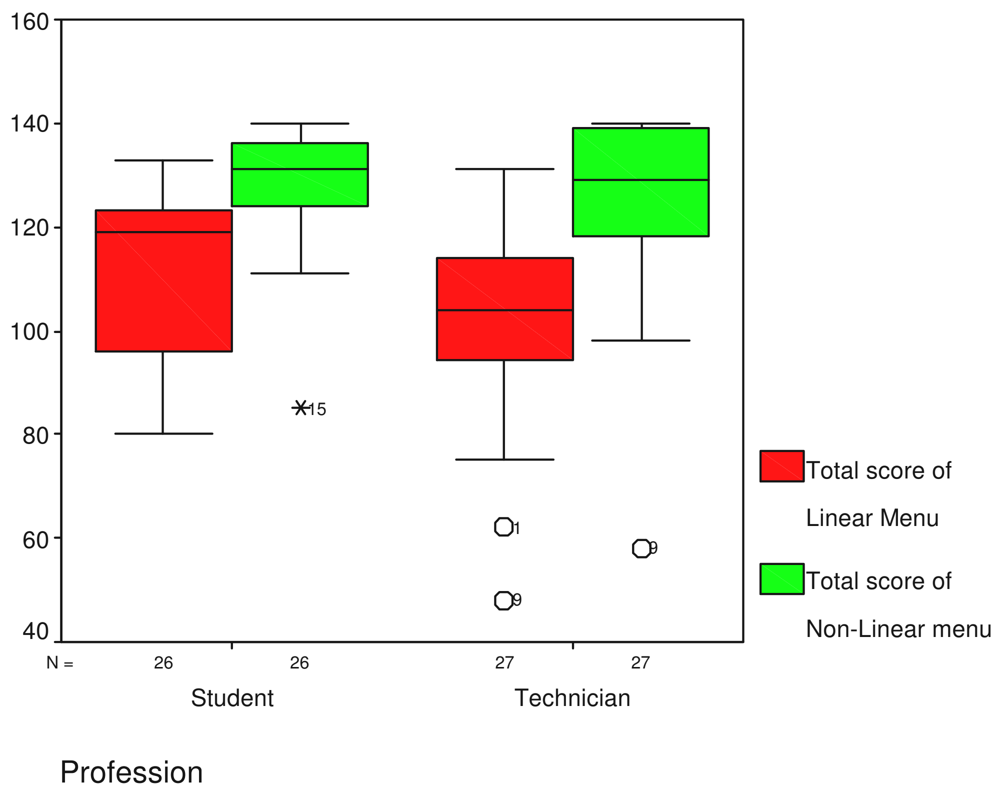

Figure 7-8 Profession Vs satisfaction score

In case of non-linear menu student's average rating 127.7 (N=26, SD= 12.45) is partially higher than technicians average rating 125.1(N=27, SD= 18.52).

The analysis of variance (ANOVA) test was performed to determine the statistical significance. The analysis of variance of profession shows significant difference neither in linear menu ($F_{1,51}$= 3.11, p >0.0169) nor in non-linear menu ($F_{1,51}$=.35, p > 0.0169) on the satisfaction score. Based on the findings and statistical test we cannot conclude if there is any significant effect of profession on the use of two types of menu.

7.1.2.2.2 Gender Vs satisfaction score

In our experiment there were 19 female participants and 34 male participants, let us analyse, if there is significant effect of gender on the use of both menu types. As the box plot (figure 7-9) shows and statistics determines there is in general trend of higher score in case of non-linear menu, independent of gender. Females rated 104.8 (SD= 18.31) to linear menu and 127.7(SD= 9.31) to non-linear menu, whereas males rated 108.0 (SD= 18.76) to linear and 125.6 (SD= 18.47) to non-linear menu.

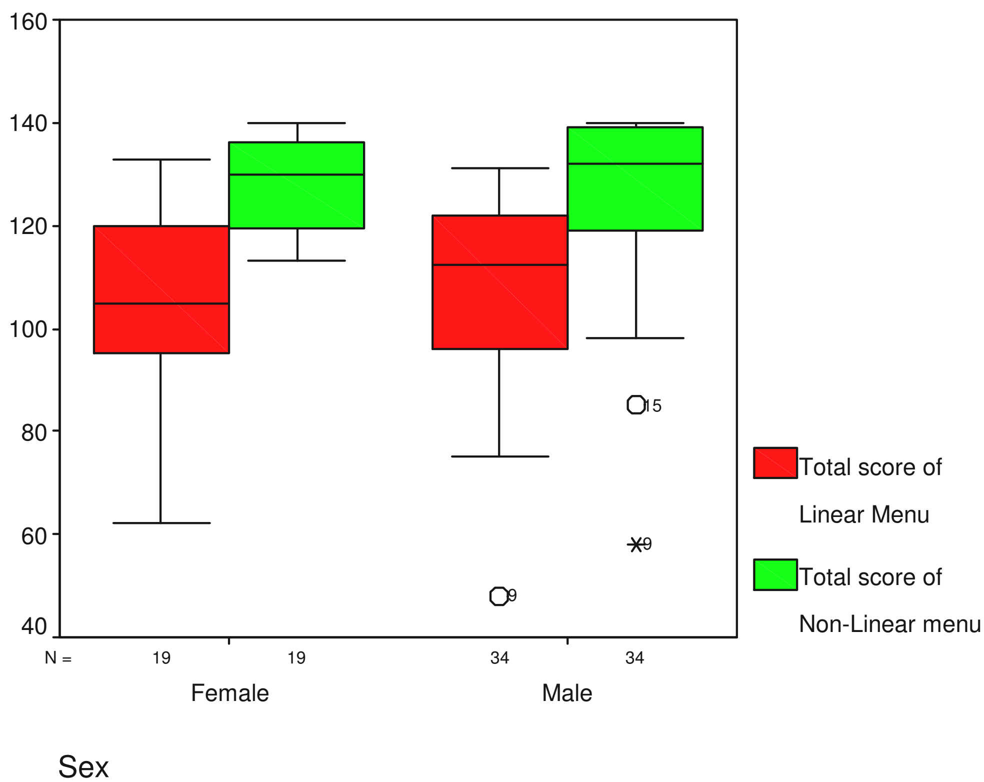

Figure 7-9 Gender Vs satisfaction score

The one-way analysis of variance (ANOVA) test was performed to determine the statistical significance between gender and type of menu use. The analysis of variance of gender shows significant difference neither in linear menu ($F_{1,51}$= .346, p >0.0169) nor in non-linear menu ($F_{1,51}$= .222, p > 0.0169) on the satisfaction score. Based on the result and statistical analysis we cannot conclude if there is any significant effect of gender on the use of two types of menu.

7.1.2.2.3 Age Vs satisfaction score

There were four participants below the age 20, 34 participants in the age group 21-35, 11 participants between 36-50, 3 participants between 51-65 and one above 65 in our experiment. All of them rated non-linear menu with higher satisfaction than linear menu as indicated in figure 7-10.

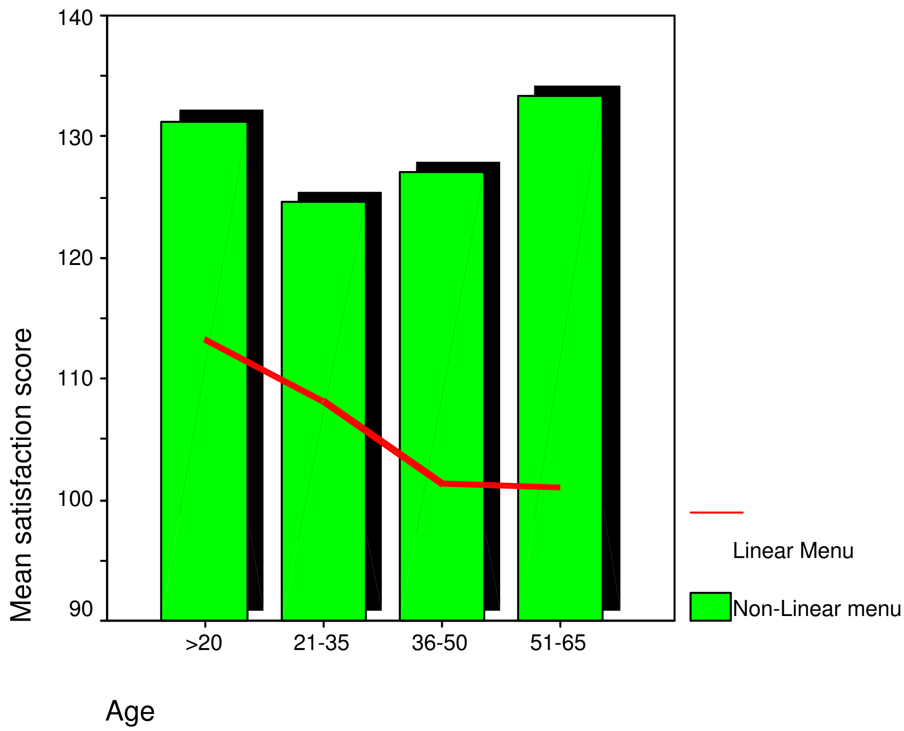

Figure 7-10 Age Vs Satisfaction score

The analysis of variance (ANOVA) test was performed to determine the statistical significance between age and type of menu use. The analysis of variance of age demonstrates no significant difference either in linear menu ($F_{4, 48}$= .565, p >0.0169) or in non-linear menu ($F_{4, 48}$= .521, p > 0.0169) on the satisfaction score. Based on the result and statistical analysis we cannot decide if there is any significant effect of age on the use of two types of menu.

Result summary:

1. The descriptive analysis of data validate our alternate hypothesis and clearly indicate that there is change in satisfaction score of two menus [mean SS_L =106.9, mean SS_{NL}= 126.4 (**SS_L < SS_{NL}**)].

2. There were 26 users, who have given full points (satisfaction score) to the non-linear menu; however, no user has given full points to linear menu in case of task 1.

3. In case of task 2, 24 users have given highest rating to non-linear menu. It was three times higher against eight users, who have given highest rating to linear menu.

4. In case of task 3, twelve users have given highest rating to linear menu is nearly half as compared to 23 users who have given highest rating to non-linear menu.

5. Analysis of all the three tasks and rating given by users indicates that, though increasing no. of users given higher rating to linear menu (Task1: 0, Task 2:8,Task 3: 12) however they are still lying below to non-linear menu (Task 1: 26, task 2: 24, Task 3: 23)

6. The analysis of variance of profession shows significant difference neither in linear menu ($F_{1,51}$= 3.11, p >0.0169) nor in non-linear menu ($F_{1,51}$= .35, p > 0.0169) on the satisfaction score. It cannot be concluded, if there is any significant effect of profession on the use of two types of menu.

7. The analysis of variance of gender shows significant difference neither in linear menu ($F_{1,51}$= .346, p >0.0169) nor in non-linear menu ($F_{1,51}$= .222, p > 0.0169) on the satisfaction score. One cannot conclude if there is any significant effect of gender on the use of two types of menu.

8. The analysis of variance of age demonstrates significant difference neither in linear menu ($F_{4,48}$= .565, p >0.0169) nor in non-linear menu ($F_{4,48}$= .521, p > 0.0169) on the satisfaction score. It cannot be decided if there is any significant effect of age on the use of two types of menu.

7.1.2.3 Error Analysis for alternate hypothesis (H_1)

H_1: There is difference between error committed in linear and non-linear menu $E_L > E_{NL}$

In the following Table 7-10, task wise result is summarised for both the cases.

Task	Linear menu	Non-linear menu
Task1	10.5	1.0
Task2	5.0	2.1
Task3	1.8	0.7
Overall	**17**	**4**

Table 7.10 Mean error Vs menu type

Mean error committed for task1, task 2 and task 3 were found approximately 11, 5 and 2 for linear menu, while they were found one, two and one respectively for non-linear menu. Overall analysis reveals that an average user made 17 errors (N=53, SD = 11.61, S.E.M = 1.59) in case of linear menu where as to perform the same tasks in non-linear menu it was only four (N=53, S.D = 5.35, S.E.M = 0.73). Calculation of these errors was based on roll backing and wrong path followed to complete the task. Apart from that evaluator recorded in some cases error caused due to misunderstanding of menu structures (viz. some users were frequently confused to click on 'new" or 'database' as the task was to create new database), meaning of menu content, and their arrangement together. Due to limited space, 'new' as keyword is being used under which subsequent content has been branched in hierarchical order. One may consider it as a smart kind of logical ordering. This kind of arrangement is used often in case of linear menu working well with the use of most common type of desktop at home and office.

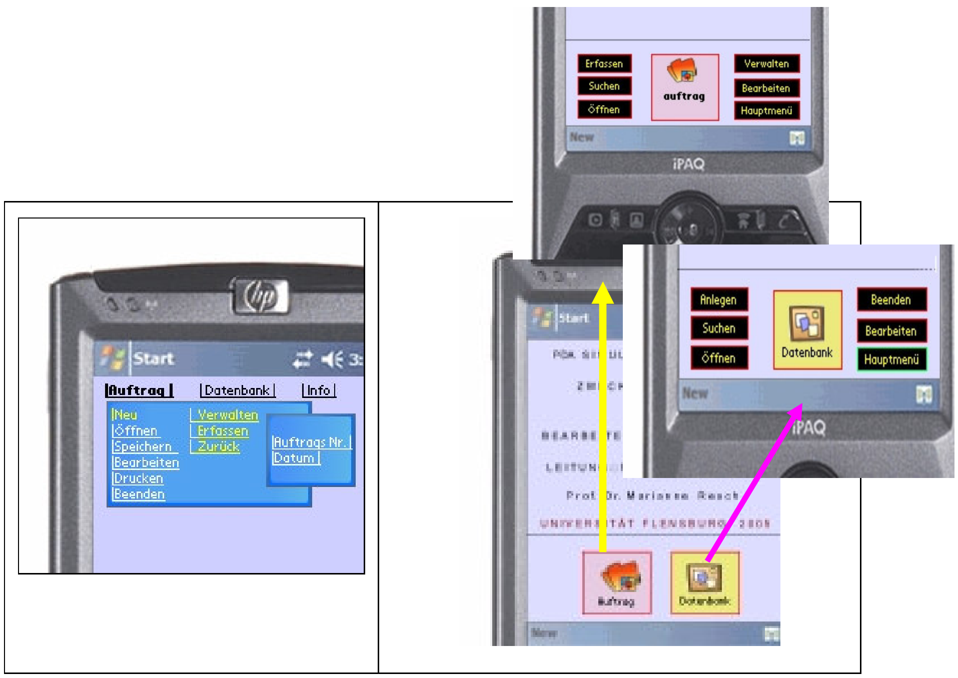

Figure 7-11 Two type of menu showing different approach to proceed

After clicking on 'new', users have had two options 'manage' or 'create' to proceed. It means this path should be followed if user wants to create new contract or to manage contracts. However, if user wants to manage database related uses, it was being realised by placing a keyword namely 'database' at the same level where 'new' was placed. Linear menu allowed branching out of related contents in a menu group. This created confusion to the users if task has the same keyword in their content (e.g. please create a new database). In this case users often recalled the 'new' to create new database as well, however this 'new' was only meant for contract related jobs. Users tried immediately by hit and trial method to get into the application and resulted into making more errors. Where as, in case of non-linear menu users have had option to follow a clear path.

There were 49 cases (N=53) in which total error committed in non-linear menu were less than linear menu. We want to mention it explicitly here; smaller the error leads to the lower complexity of using menu. Test also confirms that mean error committed in case of linear menu found to 17 where as only 4 in case of non-linear menu. Hence, we can conclude $\mathbf{E_{NL} < E_L}$.

Let us examine task wise error rate to understand the amount of complexity based on error made in each task separately.

7.1.2.3.1 Task 1: subject Vs error

There were only 10 subjects who committed errors in case of non-linear menu; however, in case of linear menu there were only two subjects (51 subjects committed at least one error) who finished the task without making any error.

Result of Task 1 favours non-linear menu largely as 51 users committing error in case of linear menu against only two users are making error to complete the same task in non-linear menu (figure 7-12).

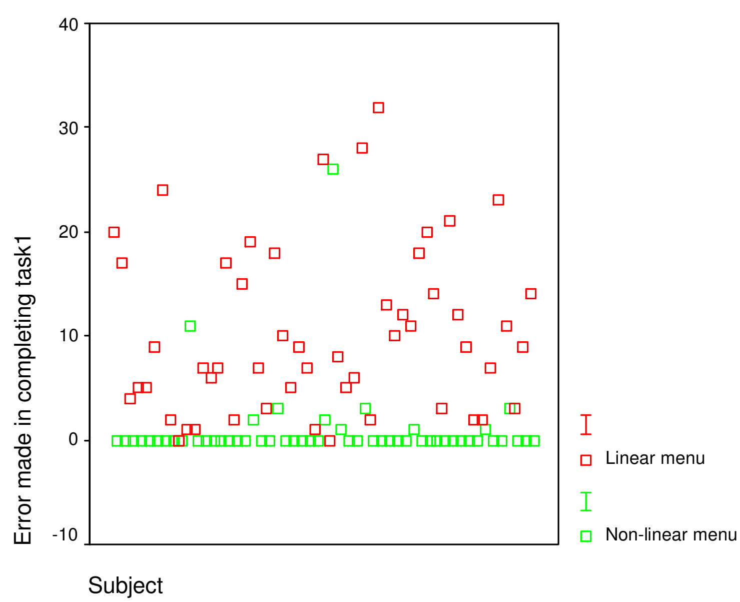

Figure 7-12 Chart showing distribution of error committed in task 1

7.1.2.3.2 Task 2: subject Vs error

In case of task 2, users made more errors while performing the task in non-linear menu though they are less in number as compared to linear menu. The highest no. of error committed in task 2 is 32 whereas the same user is committing eight errors to finish the task in non-linear menu. The maximum number of errors committed in case of non-linear menu is 14.

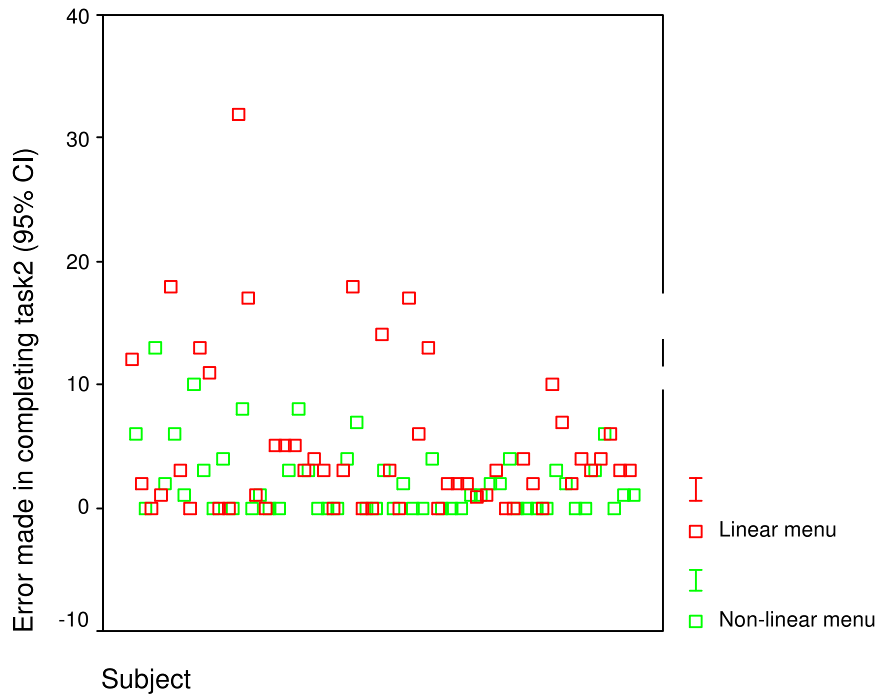

Figure 7-13 Chart showing distribution of error committed in task 2

It has also been found there were 40 users who committed at least one error while performing task in linear menu whereas in case of non-linear menu it falls to 27. In other words, only 13 participants were able to finish the task in linear menu without making any error whereas 26 participants (truly double) successfully finished the job without making any error in non-linear menu (see figure 7-13).

7.1.2.3.3 Task 3: subject Vs error

In case of task 3, 28 participants made more than one error while there were only 15 participants who made error in case of non-linear menu. Distribution plot shows that highest number of errors made by any user was 24 and fairly higher than 14 errors made by participants in case of non-linear menu. However in both cases the majority of users making errors (figure 7-14) within the range of 1 to 7, users are making less error (Mean= 0.75, SD= 2.07) in case of non-linear menu as compared to linear menu (Mean = 1.83, SD=3.82).

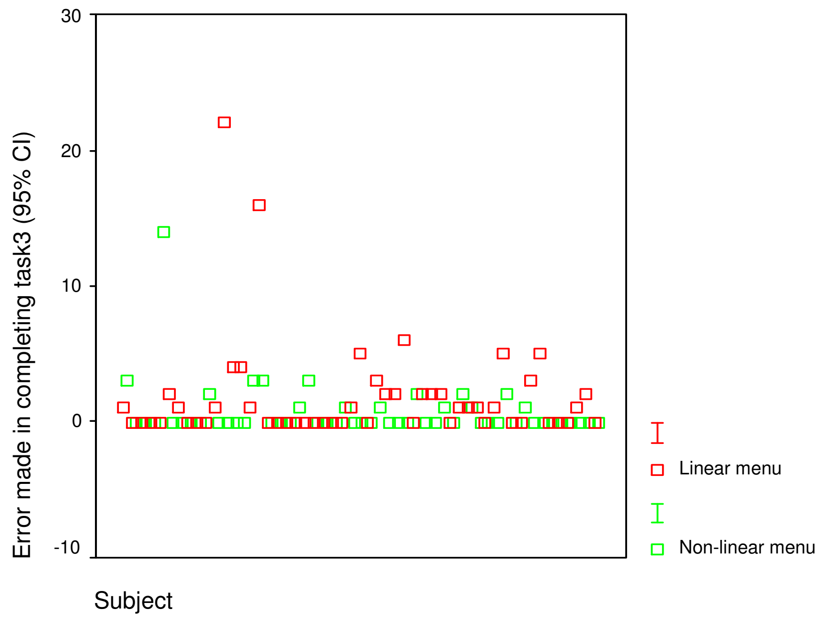

Figure 7-14 Chart showing distribution of error committed in task 3

Analysis of the entire task with respect to error made by users indicates, more and more users are making less error as the task approaches from one to three in case of linear menu. Figure 7-15 shows the distribution of error made by all the users (N= 53).

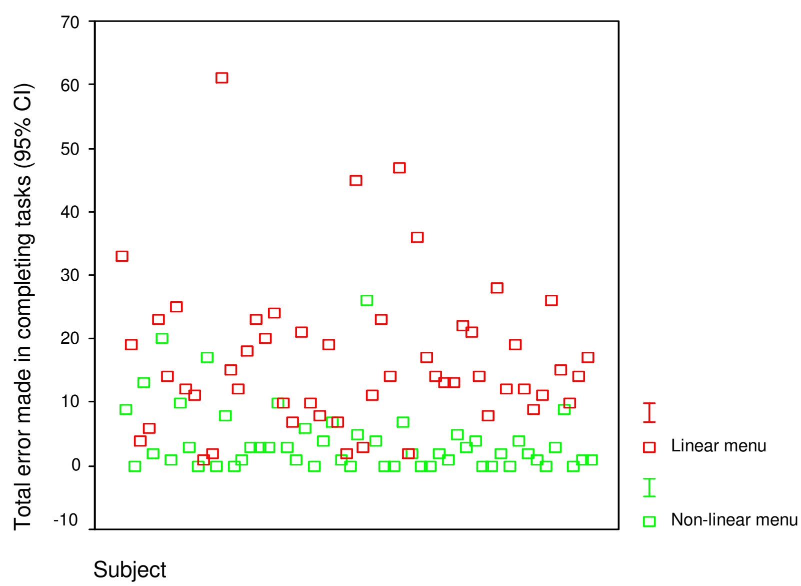

Figure 7-15 Chart showing distribution of error committed in entire task

From the figure 7-15 it is noticeably indicated that density of error in case of non- linear menu is mostly on lower region (0-5) and distributed in a range of 0 to 10 (see box plot, figure 7-16). However, errors in case of linear menu are evenly distributed and ranges from zero to 35 (refer to box plot, figure 7-16). The majority of the users are distributed in the region of 10 to 20 errors.

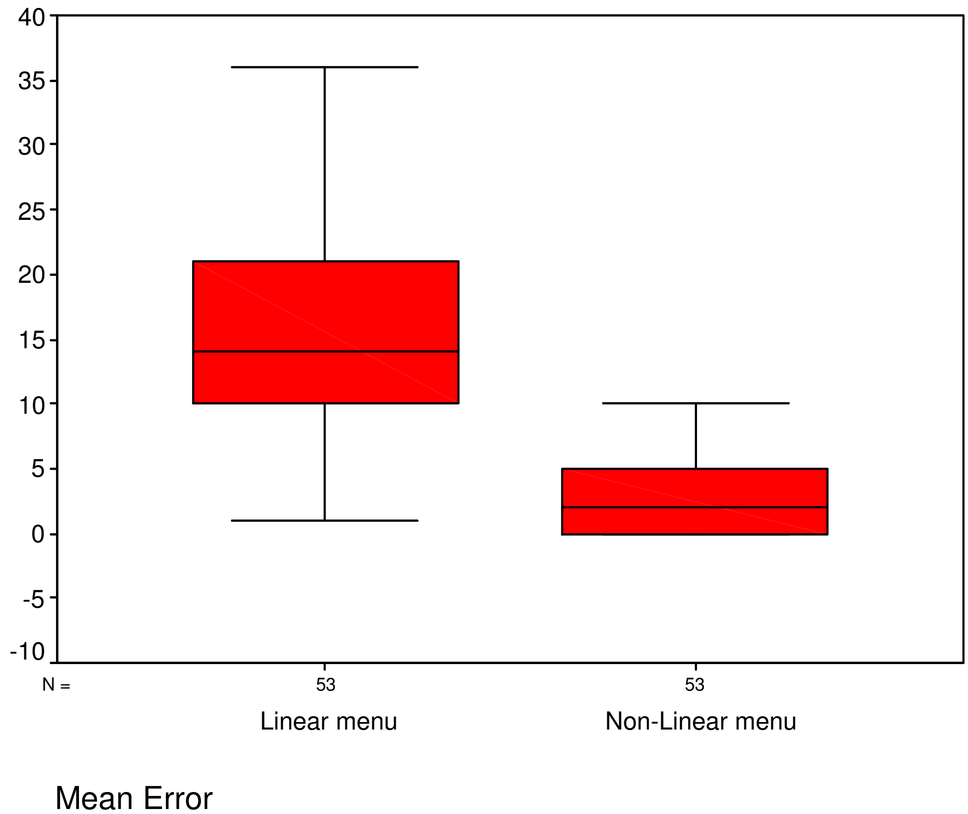

Figure 7-16 Box plot of mean error committed in two types of menu

Mean error box plot drawn at 99% of confidence interval showing that there is an evident difference between the error values in two types of menu. There is statistically significant difference among the error value between linear (Mean= 16.66, SD= 11.61, Min= 1, Max= 61) and non-linear menu (Mean =3.91, SD=5.35, Min=0, Max=21). These results are validating once again our alternate hypothesis "same user makes more error in linear menu than in non-linear menu".

7.1.2.4 Error Analysis under MTO aspect:

Similar to user's satisfaction, we will analyse error occurrences with respect to factors viz. profession, gender, and age.

7.1.2.4.1 Profession Vs error

We have tested 26 students and 27 technicians with the view that if their profession play a role on menu use pattern. A box plot of total error committed by respective group of sample is shown in figure 7-17.

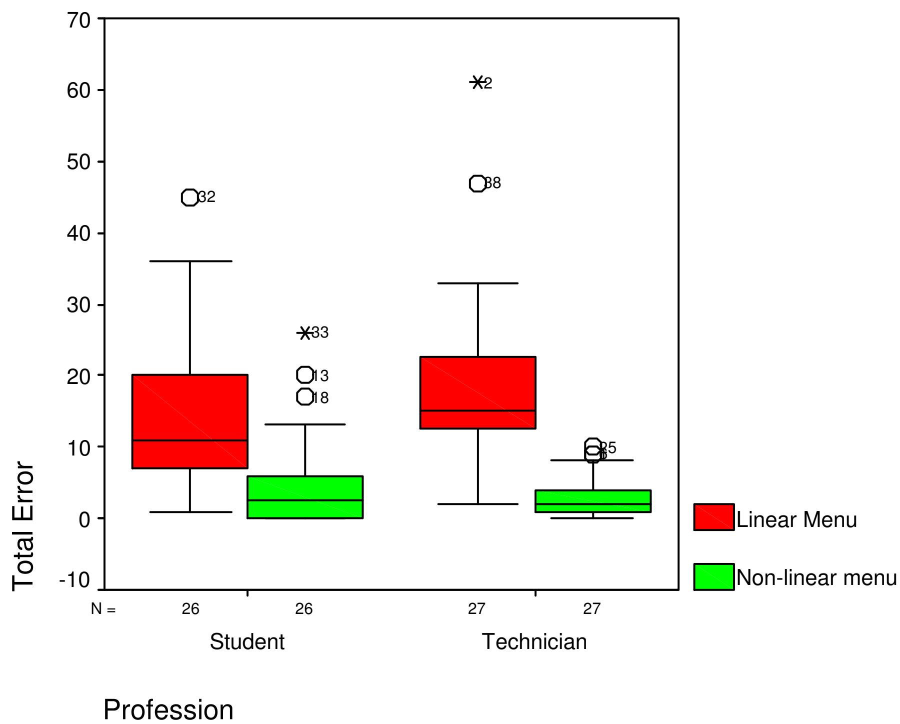

Figure 7-17 Profession Vs error

We found both the subject groups made considerably fewer errors by completing entire task in non-linear menu. Students committed average 14 error (SD= 10.60), whereas technicians 19.2 (SD= 12.16) in case of linear menu. Maximum number of error made found 45 (student) and as high as 61(technician) in case of linear menu. In case of non-linear menu, average error made found considerably lower (student: mean=4.8, SD= 6.95, max= 26; technician: mean= 3.0, SD= 3.04, max=10). By comparing these results, one outcome makes a sense of worthiness to mention here. Maximum no. of error committed by any technician [S2: 61][69] in linear menu found higher than student [S32:45] but in case of non-linear menu, maximum no. of error committed by any student [S33:26] is found higher than technician [S25:10]. It may point toward likelihood for technicians to make more error is large in linear

[69] [X,Y]: X= Subject, Y= Value

menu rather than non-linear menu.

The analysis of variance (ANOVA) test was performed to determine the statistical significance of profession on error possibility in both types of menu. The analysis of variance of profession shows no significant difference either in linear menu ($F_{1, 52}$= 2.76, p >0.0169) or in non-linear menu ($F_{1, 52}$= 1.46, p > 0.0169) on the error. Based on the findings in view of error possibility, we cannot conclude if there is any significant effect of profession on the use of two types of menu.

7.1.2.4.2 Gender Vs error

Test statistics result of 19 female participants and 34 male participants came across that there is in common tendency of making less error in case of non-linear menu (figure 7-18). Females made average 14.8 (SD= 11.28) errors in linear menu and 4.6 (SD= 7.23) in non-linear menu, whereas males made 17.6 (SD= 11.84) errors in linear and 3.5 (SD= 4.01) errors in non-linear menu.

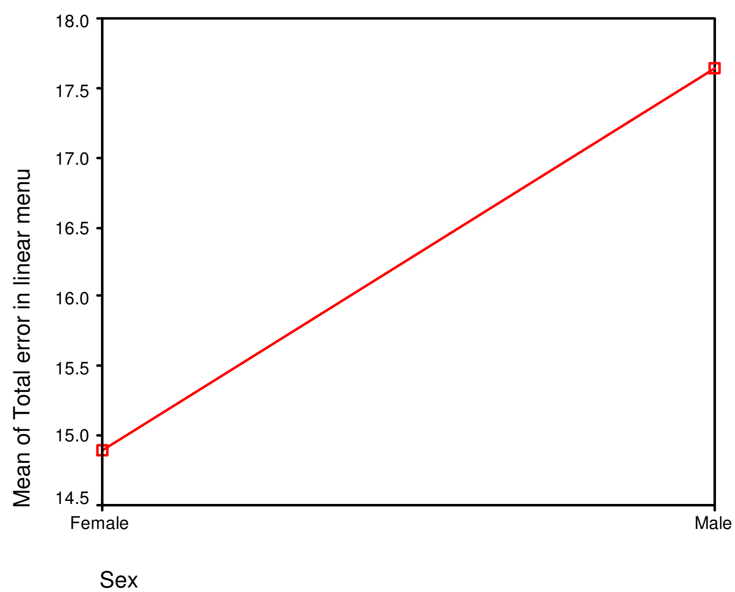

Figure 7-18 Gender Vs mean of total error in linear menu

Figure 7-18 reveals females are making less error in linear menu than males but quite the opposite they are committing more error in non-linear menu than males (as shown in figure 7-19). However, common trend indicates an effect of gender on complexity (interms of error) of menu type, test of significance is needed to draw conclusion.

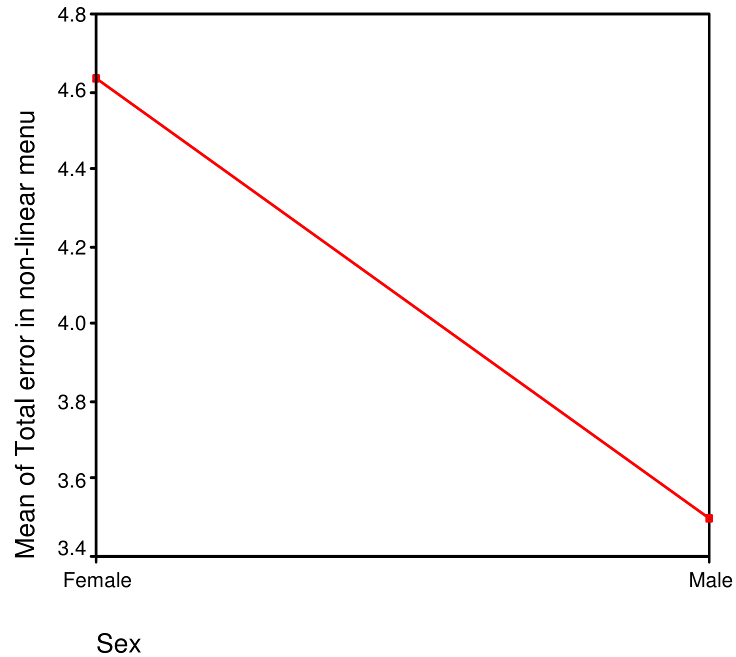

Figure 7-19 Gender Vs mean of total error in l non-linear menu

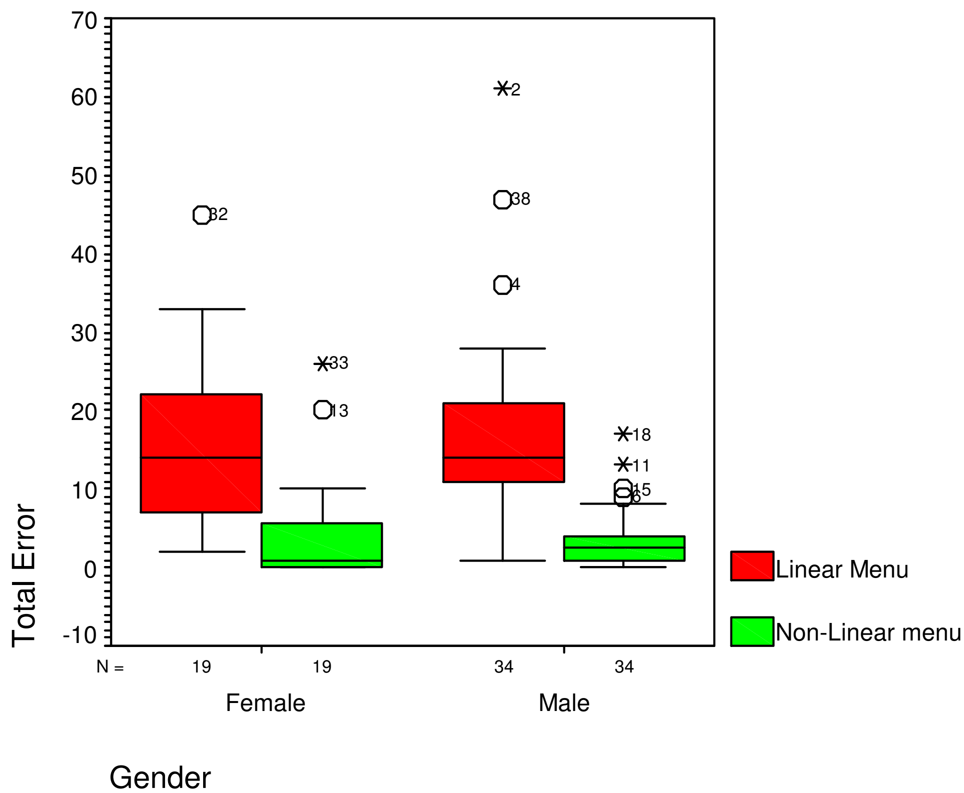

Figure 7-20 Gender Vs. error

The one-way analysis of variance (ANOVA) test was performed to determine the statistical significance between gender and error made while working on two different types of menu. The analysis of variance of gender demonstrates significant difference neither in linear menu ($F_{1, 51}$= .680, p >0.0169) nor in non-linear menu ($F_{1, 51}$= .540, p > 0.0169) on the error committed. Hence, we cannot conclude if there is any significant effect of gender on the use of two types of menu.

7.1.2.4.3 Age Vs. error

Participant of all age group made less error in non-linear menu than linear menu as indicated in figure 7-21. Error rate was measured relatively high in linear menu in the age group of 51-65.

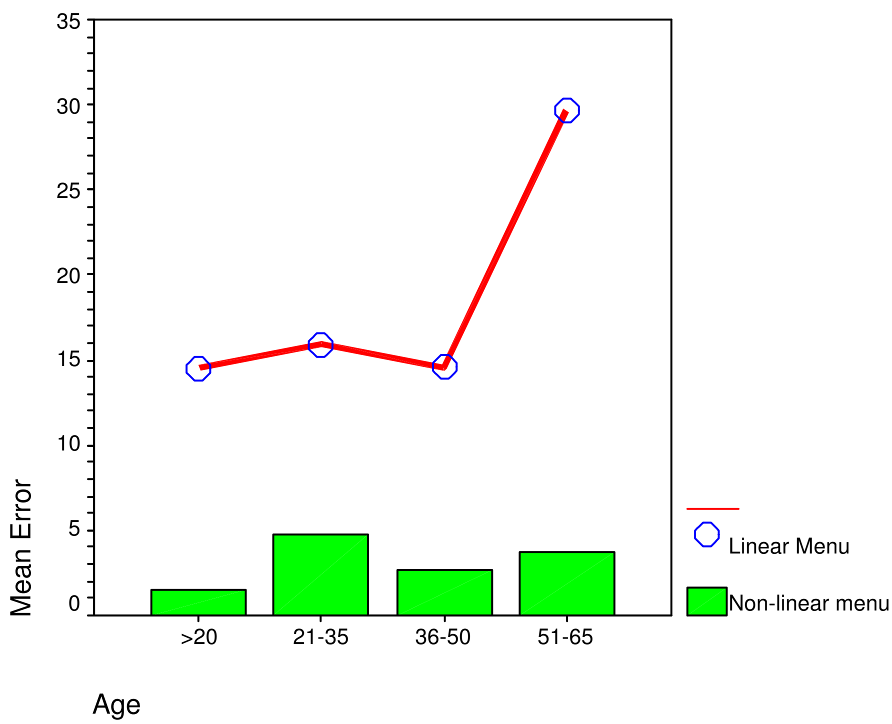

Figure 7-21 Age Vs. error

The analysis of variance (ANOVA) test was performed to verify the statistical significance of age on possibility of error. The analysis of variance expresses no significant difference of age on error neither in linear menu ($F_{4, 48}$= 1.92, p >0.0169) nor in non-linear menu ($F_{4, 48}$= .678, p > 0.0169). Based on the above result and statistical analysis we can conclude there is no significant effect of age on the use of two types of menu.

Result review:

1. Statistical data validate our alternate hypothesis and clearly indicate that there is change in mean error rate of two menus (**$E_{NL} < E_L$**). There were 49 cases (N=53) in which total error committed in non-linear menu were less than linear menu.

2. Outcome of task 1 favours non-linear menu largely as 51 users committing error in case of linear menu against only two users are making error to complete the same task in non-linear menu.

3. Only 13 participants were able to finish the task 2 in linear menu without making any error, it was just half that of non-linear menu.

4. In case of task 3, 28 participants ended up with more than one error while there were only 15 participants who made at least one error in case of non-linear menu.

5. There is a significant difference among the error value between linear (Mean= 16.66, SD= 11.61, Min= 1, Max= 61) and non-linear menu (Mean =3.91, SD=5.35, Min=0, Max=21).

6. The analysis of variance of profession shows significant difference neither in linear menu ($F_{1,51}$= 2.76, $p > 0.05$) nor in non-linear menu ($F_{1,51}$= 1.46, $p > 0.05$) on the error. Hence, it cannot be concluded, if there is any significant effect of profession on error probability during the use of two types of menu.

7. The analysis of variance of gender demonstrates significant difference neither in linear menu ($F_{1, 51}$= .680, $p > 0.0169$) nor in non-linear menu ($F_{1, 51}$= .540, $p > 0.0169$) on the error committed. Hence, we cannot conclude if there is any significant effect of gender on the use of two types of menu.

8. The analysis of variance expresses no significant difference of age on error either in linear menu ($F_{4,48}$= 1.92, $p > 0.05$) or in non-linear menu ($F_{4,48}$= .678, $p > 0.05$). It cannot be concluded if there is any significant effect of age on error while using two types of menu.

7.1.2.5 Time analysis for alternate hypothesis (H_1)

H_1: users take more time in linear menu to complete the task than in non-linear menu ($T_L > T_{NL}$)

T-Test for significance of difference

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Time taken in linear menu - Time taken in non-linear menu	109.6	67.6856	9.2973	90.917	128.2	11.79	52	.000

Table 7.11 Paired sample t-test for time taken in linear and non-linear menu

We have already tested the normality of distribution in null hypothesis section. Paired sample t-test statistics (Table 7.11) confirm that mean time taken to complete the task in linear menu (M=239.402, SD=67.88) is significantly more than mean time taken to complete the task in non-linear menu (M= 129.828, SD =29.67) (t_{52}= 11.785, p<.001).

7.1.2.5.1 Task1: subject Vs time taken

Mean time taken to complete task 1 in linear menu found (M= 119.42, SD= 44) considerably more (almost double) than that of non-linear menu (M=56.68, SD=21.12). As shown in figure 7-22, there were only five occasions where graph is intercepting, pointing out to subjects in cases where they have taken equal time to complete the tasks in both menus.

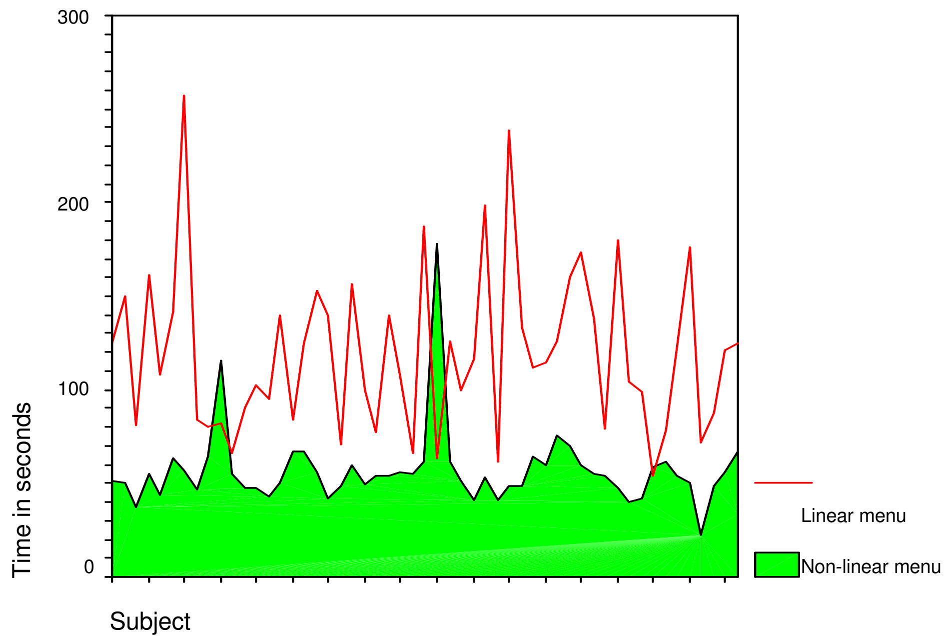

Figure 7-22 Comparison graph of task1 vs. time taken by subjects

Minimum time taken to complete task 1 was found 54.3 seconds, which is in fact close to average time taken to complete task in non-linear menu (56.7s). This outcome indicates that user could complete the task in linear menu as fast as an average user does it in non-linear menu. If we analyse the graph shown in figure 7-22, only 5 users (N=53) were near to this value.

In contrast to 54.3 seconds in linear menu, fastest user of non-linear menu took only 22.1 seconds. Slowest user took 257.2 s in linear menu whereas maximum time taken to complete the task in non-linear menu found 177.6s. Remarkably, the slowest user in case of non-linear menu was found third fastest user of linear menu.

7.1.2.5.2 Task 2: subject Vs time taken

Mean time taken to complete task2 in linear menu found (M= 53.85, SD= 37.71) considerably more (over double) than that of non-linear menu (M=23.71, SD=16.46). There were only eight occasions where graph is intercepting, pointing out to subjects in cases where they have taken equal or less time to complete the tasks in linear menu as compared to non-linear menu (figure 7-23).

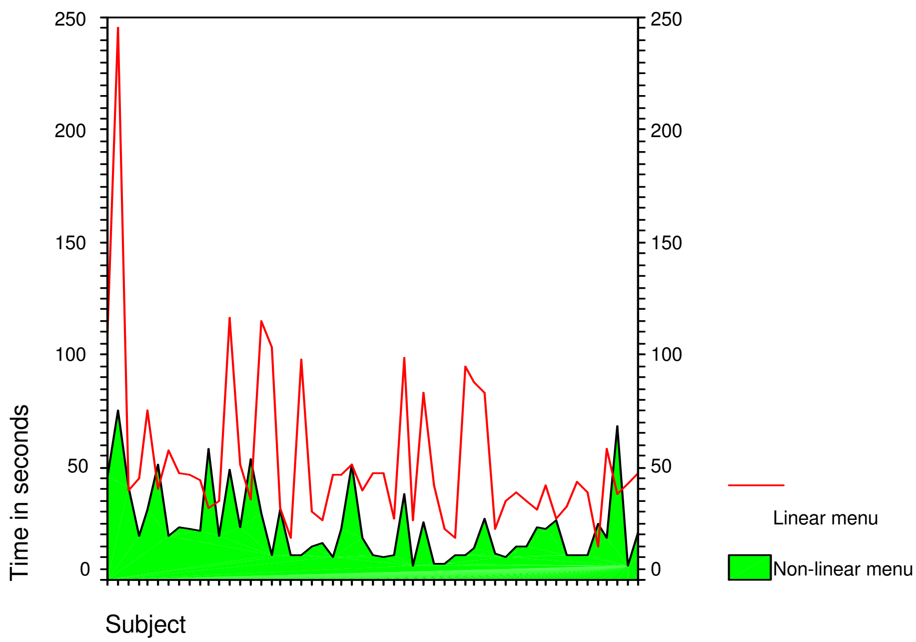

Figure 7-23 Comparison graph of task2 Vs time taken by subjects

Minimum time taken to complete task2 in linear menu was found 14.6 seconds slightly more than double as compared to 6.3s of non-linear menu. Slowest user took 245.7s in linear menu whereas maximum time taken by a user to complete the task in non-linear menu found only 75s. Remarkably, the slowest user in case of non-linear menu was also found the slowest user of linear menu.

7.1.2.5.3 Task 3: subject Vs time taken

Mean time taken to complete task3 in linear menu found (M= 66.12, SD= 20.93) more than that of non-linear menu (M=49.43, SD= 15.42).

There were only seven instances where line graph is below to other, draw attention to those subjects who have taken less time to complete the tasks in linear menu than non-linear menu (figure 7-24). Figure 7-24 is showing nine intercepting points of subjects who completed the task in equal period of time.

Minimum time taken to complete task3 in linear menu was found 45.4 s, 4 ½ times than of non-linear menu (10s). Slowest user took 175.3s in linear menu whereas maximum time taken by a user to complete the task in non-linear menu found only 122.5s.

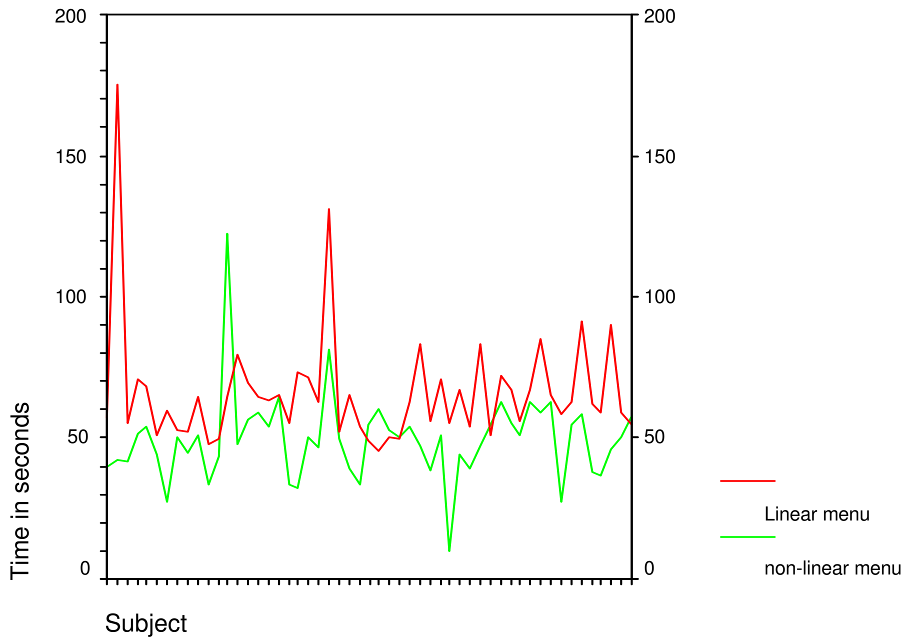

Figure 7-24 Comparison graph of task3 Vs time taken by subjects

Analysis of the entire task with respect to time taken by users indicates, almost all of users is taking more time to complete task in case of linear menu. Figure 7.25 time Vs subject showing the distribution of time taken by all the users (N= 53).

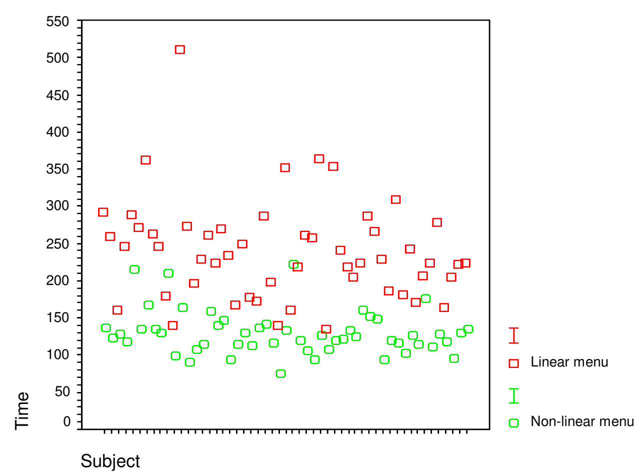

Figure 7-25 Time Vs subject

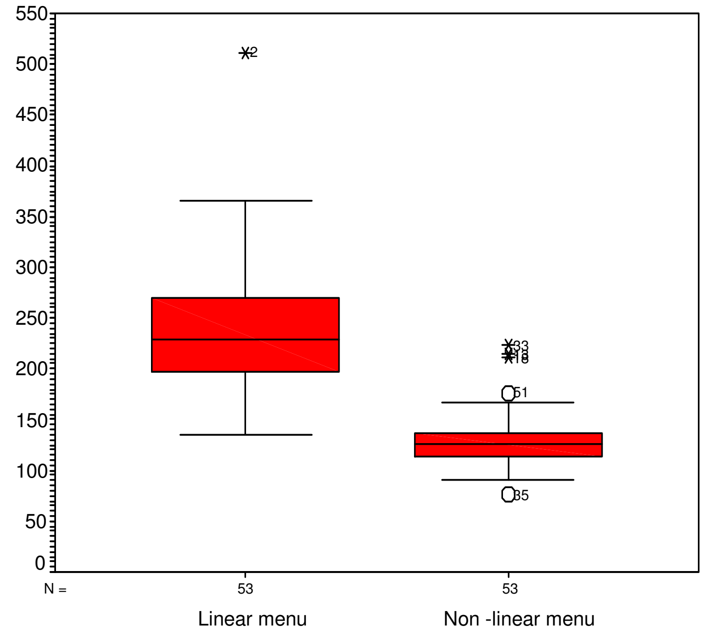

Figure 7-26 Time Vs menu type

As shown in figure 7-26, box plot drawn for time taken showing that there is an evident difference between the values in two types of menu. Two outliners (S35 & S51) and two extreme (S_{33} & S_{18}) values has been found in case of non-linear menu. There is statistically significant difference of the mean time value between linear (M=239.402, SD=67.88, Min=134.8, Max=511.4) and non-linear menu (M= 129.828, SD =29.67, Min=75.5, Max=222.9). These results are confirming our alternate hypothesis 'user takes more time in linear menu than in non-linear menu'.

7.1.2.6 Time Analysis under MTO aspect

Time taken to complete the task is one very central aspect of complexity issue addressed by menu interface. We are analysing variations in time taken recorded for individual user under the light of their profession, gender, and age in following paragraphs.

7.1.2.6.1 Profession Vs time

26 students and 27 technicians have been tried out with the objective to know if their professions play a role on menu use pattern and the time they are spending to finish the task. A box plot of total time taken by respective group of sample is shown in figure 7-27.

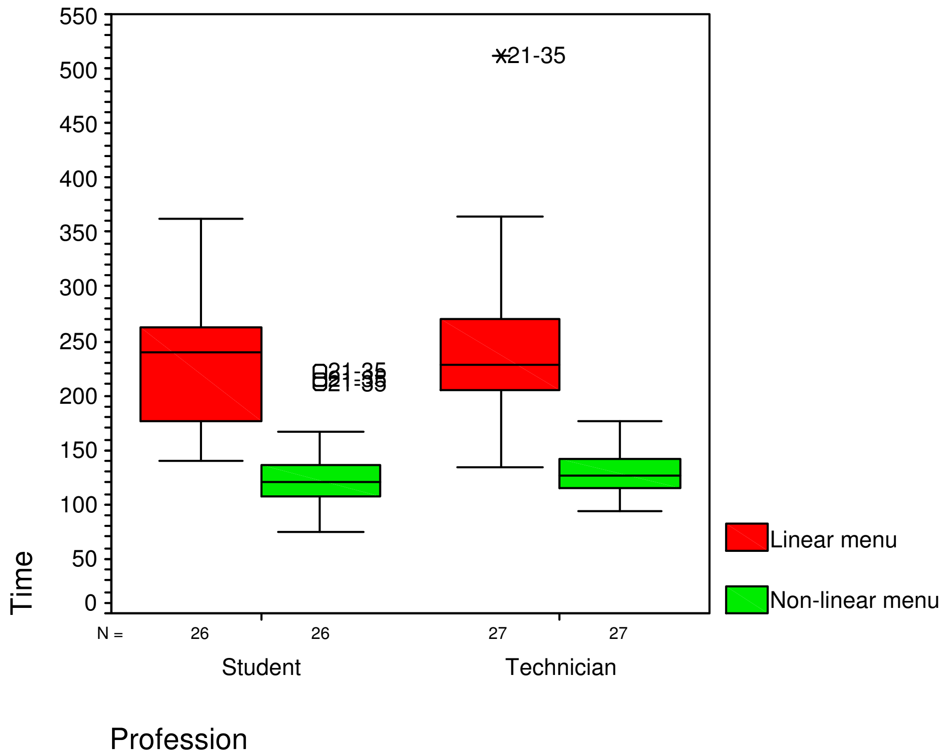

Figure 7-27 Profession Vs time

We found both the subject groups took notably shorter time in completing entire task in non-linear menu. Students took average 233.8s (SD= 63.58) and technicians 244.78s (SD= 72.57) in case of linear menu. Maximum time spent found 362s (student) and as high as 511.4 s (technician) in case of linear menu. While comparing the results, average time spent found in non-linear menu considerably lower (**Student:** Mean=129.65, SD= 37.42, Max= 222; **Technician:** Mean= 129.99, SD= 20.36, Max=176). Analysis of box plot shown above we found three students (S_{12}, S_{18} & S_{34}) took exceptionally more time to complete the task in non –linear menu. Fastest subject was found a student (75.5s) in non-linear menu while fastest technician took 93.3s to complete the task. Surprisingly fastest subject found technician (134.8s) in case of linear menu while fastest student took 140.4 s to complete the same task.

The analysis of variance (ANOVA) test was performed to determine the statistical significance of profession on time spent in both types of menu. The result shows no significant effect of profession either in linear menu ($F_{1, 51}$= 0.34, $p > 0.0169$) or in non-linear menu ($F_{1, 51}$= .002, $p > 0.0169$).

7.1.2.6.2 Gender Vs time

Test statistics result of 19 female participants and 34 male participants state that there is in common tendency of taking less time in case of non-linear menu (figure 7-28).

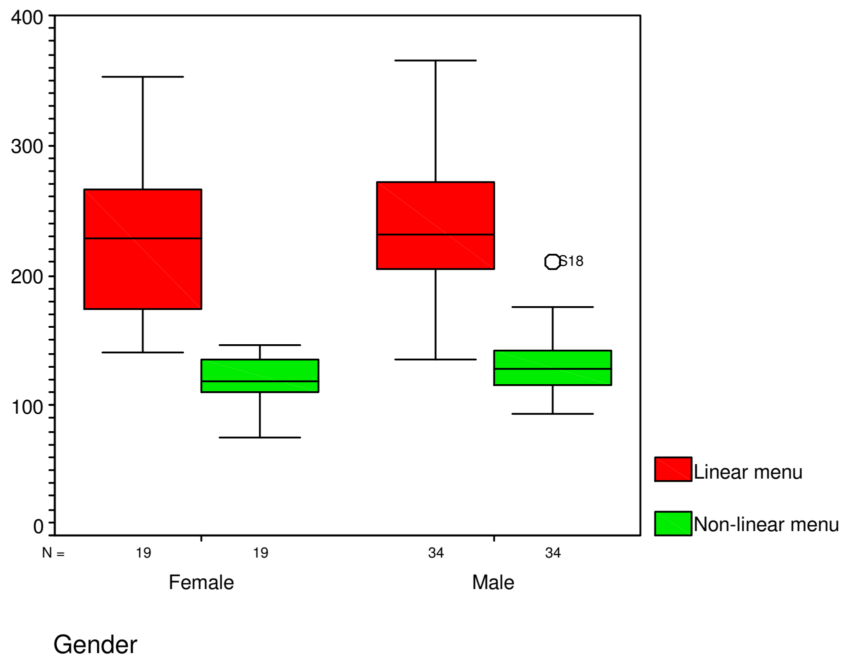

Figure 7-28 Gender Vs time

Females took average 225.4s (SD= 58.6) in linear menu and 126.9s (SD= 36.9) in non-linear menu, whereas males took 247.2s (SD= 72.2) in linear and 131.4s (SD= 25.2) in non-linear menu.

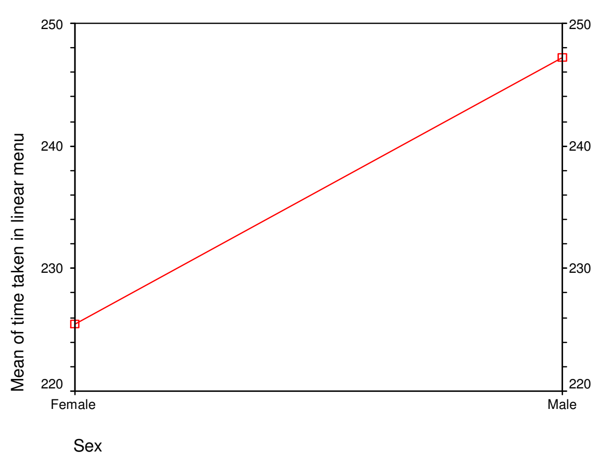

Figure 7-29 Gender Vs mean of time taken in linear menu

Figure 7-29 & 30 reveals, in-general females spent comparatively less time than males to complete the task in both menus. However, common trend indicates an effect of gender on menu use, test of significance is needed to draw conclusion.

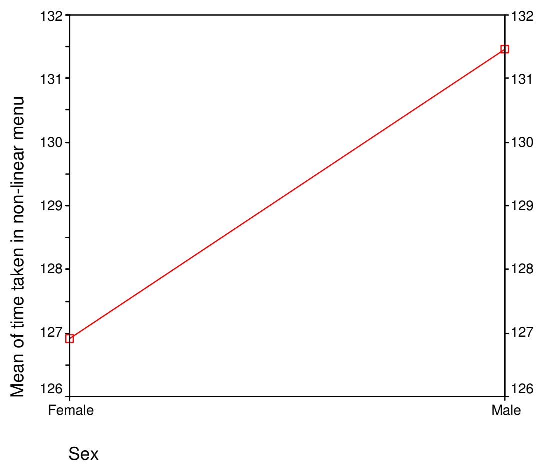

Figure 7-30 Gender Vs mean time taken in non-linear menu

The one-way analysis of variance (ANOVA) test was performed to determine the statistical significance between gender and time taken while working on two different types of menu. The analysis of variance of gender demonstrates significant difference neither in linear menu ($F_{1, 52}$= 1.25, p >0.0169) nor in non-linear menu ($F_{1, 52}$= .280, p > 0.0169) on time taken. Hence, we cannot conclude if there is any significant effect of gender on the use of two types of menu.

7.1.2.6.3 Age Vs time

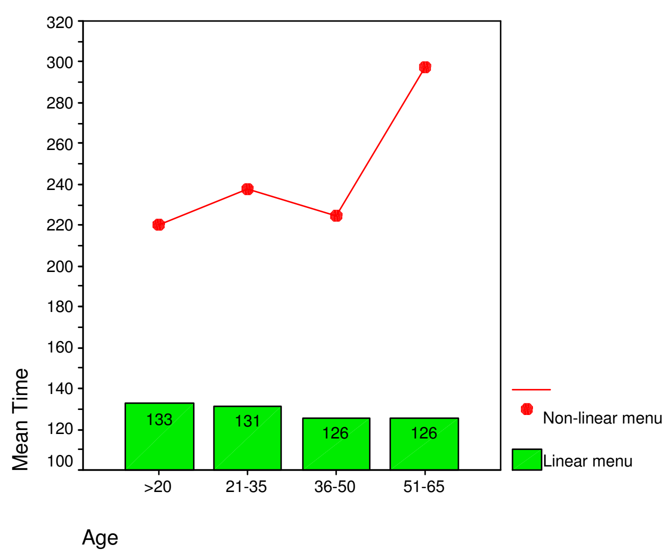

Figure 7-31 Age Vs mean time

Participant of all age group took less time in non-linear menu than linear menu as indicated in figure 7-31. Mean time taken was found relatively high in linear menu in the age group of 51-65, however this age group registers faster to finish the task in non-linear menu than other.

Age group of 51-65 indicates opposite effect whereas age group of 36-50 shows similarity. The analysis of variance (ANOVA) test was performed to verify the statistical significance of age on speed of finishing the task.

The analysis of variance of ages express no significant difference of time on both in linear menu ($F_{4, 48}$= 1.54, p >0.0169) and in non-linear menu ($F_{4, 48}$= .125, p > 0.0169). Based on the above result and statistical analysis we can conclude that there is no significant effect of age on the speed of finishing the task with given two types of menu.

Result review:

1. The results of paired sample t-test statistics confirm that mean time taken to complete the task in linear menu (M=239.402, SD=67.88) is significantly more than mean time taken to complete the task in non-linear menu (M= 129.828, SD =29.67) (t_{52}= 11.785, p<.0169).

2. Mean time taken to complete task 1 in linear menu found (M= 119.42, SD= 44) considerably more (almost double) than that of non-linear menu (M=56.68, SD=21.12).

3. Mean time taken to complete task2 in linear menu found (M= 53.85, SD= 37.71) considerably more (over double) than that of non-linear menu (M=23.71, SD=16.46).

4. Mean time taken to complete task3 in linear menu found (M= 66.12, SD= 20.93) more than that of non-linear menu (M=49.43, SD= 15.42).

5. Analysis of the entire task with respect to time taken by users indicates, almost all of users is taking more time to complete task in case of linear menu.

6. The result of ANOVA shows significant effect of profession neither in linear menu ($F_{1, 51}$= .34, p >0.0169) nor in non-linear menu ($F_{1, 51}$= .002, p > 0.0169) so far as the 'time taken to complete the task' is concerned.

7. The analysis of variance of gender demonstrates no significant difference between linear menu ($F_{1, 52}$ = 1.25, p >0.0169) and non-linear menu ($F_{1, 52}$= .280, p > 0.0169) on time taken. Hence, we cannot conclude if there is any significant effect of gender on time taken to complete the task, while using linear and non-linear type of menu.

8. The analysis of variance of age express no significant difference of time on both in linear menu ($F_{4, 48}$= 1.54, p >0.0169) and in non-linear menu ($F_{4, 48}$= .125, p > 0.0169). It cannot be concluded if there is any significant effect of age on time taken while using two types of menu.

7.1.2.7 Decision on alternative hypothesis (H_a)

Various tests performed on user's feedback of satisfaction, error making phenomenon and time taken to complete the task in linear and non-linear menu. The analysis and results are explained in detail. We found that these tests provide enough evidence to confirm our alternative hypothesis

7.1.3 Implications of result

Mean time taken to complete the task in linear menu found comparatively high (239s) against non-linear menu (130s). This can be understand due to the fact that, the non-linear menu can be arranged in a two dimensional way on the screen, while linear menus appear in a straight line path and do not take benefit of the two dimensional nature, they present the menu options in a linear style. In case of non-linear menu, each option is the same distance from the selection "cursor" just the direction is different; therefore the quantitative ease of selecting each menu option will be the same. There is a uniform time of selection and thus equal intensity of easiness in selecting any menu option. During the test, initially many participants resisted against non-linear menu and found not much attractive. Interestingly satisfaction rating results are showing slightly diminishing trends, however, users have taken less time to complete the task making less errors. Repeated use of non-linear menus facilitates learning of menu options at a faster rate than using linear menus. Almost all users were unfamiliar with non-linear arrangements of menus and this may caused initial resistance on the concept.

From our observation of menu use pattern by individual users, it seems that people, who understood how the structure was semantically organised, developed superior working approach with non-linear menu. This resulted in faster and an increased number of successful steps to complete the given tasks.

The task completion time and error probability in case of non-linear menu were significantly below the average of linear menu. The user satisfaction rating found higher in case of non-linear menu. It implies when people performed the task successfully, they would have been satisfied with the design and the usability rating became higher. This 'simple but important user satisfaction factor' affects the likelihood of correct interface usage. It was told by some subjects that the menu interface in case of non-linear menu was self-explanatory and they had intuitively aware where they were or where they had been in course of performing the task.

However, we have designed the menu application in such a way so that it was most suited with ‘technicians’. We assumed that a user performance also depends on the type of task they have given. We did not found any significant relevance in our study. Satisfaction rating, error committed and time taken were found un-affected of gender, age and profession as far as the difference of two menu type is concerned. This study has been carried out in Germany and there is a possibility that due to minimum basic understanding of a technique is almost same in students and technicians. However, a small differential trend cannot be ruled out. An intercultural study may produce significance of MTO concept as well. In general, analysis states that females are taking less time to complete the tasks in non-linear menu but males are also taking less time to complete the task. It could not be absolutely confirm that females are better for non-linear menu than linear menu. Similarly, it was not possible to conclude the effect of profession and age.

In the next section, we are testifying our second hypothesis.

7.2 Test of second hypothesis

As menu depth in linear menu increases user performance decreases.

As discussed in chapter methodology, user performance is addressed by efficiency and productiveness. We will test our hypothesis to efficiency and productivity of menu in following sections.

Alpha adjustment: to test our second hypothesis we have repeated measurement twice so alpha is adjusted in this case to the significance level of 2.5 % for individual measurement instead of 5 %.

7.2.1 Tests on efficiency

H_o : there is no change in efficiency of users at menu depth of d=3 and at depth of d=4 i.e. $\eta_3 = \eta_4$

H_1 : efficiency of users at d= 3 is higher than menu at d= 4 i.e. $\eta_3 > \eta_4$

7.2.1.1 Test for normal distribution

A one-sample kolmogorov-smirnov test (table 7.13) was performed on the efficiency calculated from the recorded data to confirm the normality of distribution.

Kolmogorov-Smirnov Test for normal distribution

		Efficiency at d=4	Efficiency at d=3
N		53	53
Normal Parameters [a,b]	Mean	49.7866	67.2218
	Std. Deviation	22.33649	25.61356
Most Extreme Differences	Absolute	.119	.145
	Positive	.119	.100
	Negative	-.084	-.145
Kolmogorov-Smirnov Z		.865	1.055
Asymp. Sig. (2-tailed)		.443	.215

a. Test distribution is Normal.

b. Calculated from data.

Table 7.13 Kolmogorov- Smirnov test statistics on efficiency for normal distribution

The significance value for efficiency at depth d=4 (Z_{53}= 0.865, p= 0.443) and at depth d=3 (Z_{53}=1.055, p=0.215) exceeds .05. Thus, the distribution of efficiency at menu depth of 3 as well as of 4 resembles a normal distribution. Therefore, procedures, which assume normality, can be employed for analysing these data.

7.2.1.2 Test of significance

Comparison of mean value of efficiency shows that mean efficiency in case of menu with depth d=3 (Mean = 67.22, S.D = 25.61) found higher than mean efficiency at depth d=4(Mean = 49.78, S.D = 22.33).

Since the dataset is coming from same sample group, a paired sample t-test has been performed to test the significance level of difference.

	Paired Differences					t	df	Sig. (2-tailed)
				97.5% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Efficiency at d=4 - Efficiency at d=3	-17.4352	34.29083	4.71021	-28.3071	-6.5633	-3.702	52	.001

Table 7.14 t-test statistics of efficiency at different depth of linear menu

As listed in Table 7.14, t-test performed at various depths shows a significant difference (t_{52} = -3.702, p< .025) in efficiency. Henceforth we can reject our null hypothesis ($\eta_3 = \eta_4$).

Alternatively, we have tested it for our alternative hypothesis (H_1) using Wilcoxon Signed Ranks test.

Wilcoxon Signed Ranks Test for efiiciency

		N	Mean Rank	Sum of Ranks
Efficiency at d=3 - Efficiency at d=4	Negative Ranks	16[a]	21.25	340.00
	Positive Ranks	37[b]	29.49	1091.00
	Ties	0[c]		
	Total	53		

a. Efficiency at d=3< Efficiency at d=4

b. Efficiency at d=3> Efficiency at d=4

c. Efficiency at d=4 = Efficiency at d=3

Test Statistics [b]

	Efficiency at d=3 - Efficiency at d=4
Z	-3.324[a]
Asymp. Sig. (2-tailed)	.001

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Table 7.15 Wilcoxon-Signed- Ranks test statistics on efficiency of menus at different depth

As shown in table 7.15, it has been found that η_3 is greater in 37 cases as compared to 16 of η_4 (Z_{16}=-3.324, p<. 025), which is over double (also see comparison graph of mean efficiency at different depth in figure 7-36). No ties have been found between efficiencies at different depths. Based on these statistics we can conclude that as menu depth increases in linear menu efficiency decreases.

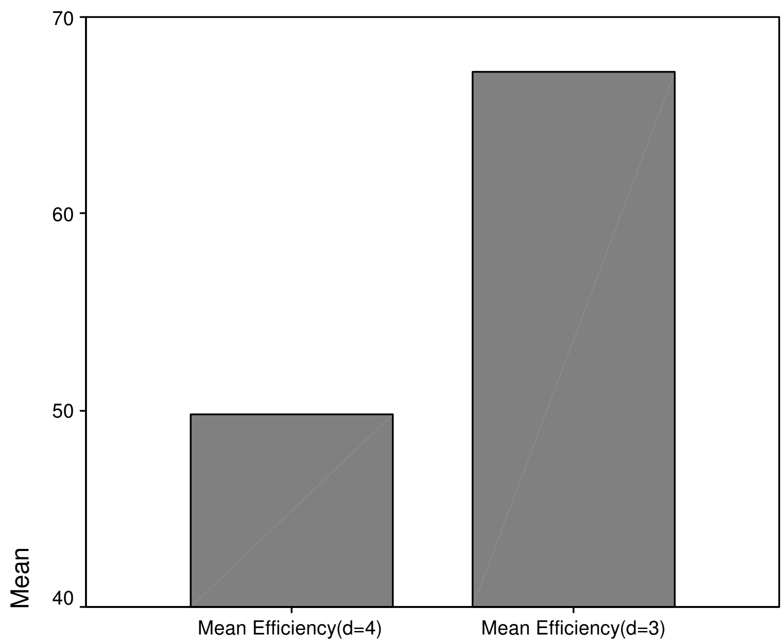

Figure 7-36 Comparison of mean efficiency at different depth

Result review:

1. The significance value for efficiency at depth d=4 (Z_{53}= 0.865, p= 0.443) and at depth d=3 (Z_{53}=1.055, p=0.215) resembles that the distribution of efficiency at menu depth of 3 as well as of 4 are normally distributed.

2. t-test confirmed that, at changed depth a significant difference (t_{52} = -3.702, p< .025) in efficiency exists. Henceforth we can reject our null hypothesis of equal efficiencies.

3. Wilcoxon Signed Ranks test confirms that η_3 is significantly higher in 37 cases as compared to 16 of η_4 (Z_{16}=-3.324, p<.025), which is over double and we can conclude $\eta_3 > \eta_4$.

7.2.2 Test on productiveness

Test hypothesis on productiveness of users with linear menu at different depth is formulated as

H_o: There is no difference in productiveness of users with linear menu at d[70]=3 and d=4 i.e. $\rho_3 = \rho_4$ and

H_1: Productiveness of users at d=3 is higher than productiveness at d= 4 i.e. $\rho_3 > \rho_4$.

We will test here our hypotheses simultaneously. Similar to the procedure followed in previous sections of this chapter, first of all normalcies of data and then significance will be tested.

7.2.2.1 Test for normal distribution

A Kolmogorov-Smirnov test was performed to verify if the data for productivity at menu depth of 3 and 4 are normally distributed. The result of test is shown in Table 7-16.

Kolmogorov-Smirnov Test for normal distribution

		Productivity at d=3	Productivity at d=4
N		53	53
Normal Parameters[a,b]	Mean	83.6605	70.7649
	Std. Deviation	14.72063	15.71212
Most Extreme Differences	Absolute	.170	.115
	Positive	.166	.083
	Negative	-.170	-.115
Kolmogorov-Smirnov Z		1.240	.835
Asymp. Sig. (2-tailed)		.092	.489

a. Test distribution is Normal.

b. Calculated from data.

Table 7-16 Normalcy test of productiveness data distribution

[70] d= depth of menu

We found that distribution data for productivity of linear menu at menu depth of 4 as well as at depth of 3 has normal distribution. In case of menu depth d=4, Z-statistics shows a larger value of significance (Z_{53}=. 835, p=. 489), p- value is significantly greater than .025 and therefore data can be taken as normally distributed. In case of menu depth d=3, p-value is just slightly greater than .05 (Z_{53}=1.240, p=. 092), overall it can be considered with greater tolerance and for the ease of analysis as normally distributed. Based on the conclusion that both the dataset are normally distributed we employed paired t-test of significance to verify our null hypothesis.

7.2.2.2 Test of significance

If we compare the mean value of productivity of users at different depths, we find at d=3 (Mean= 83.66, SD= 14.72) is higher than productivity at d=4 (Mean =70.76, SD= 15.71).

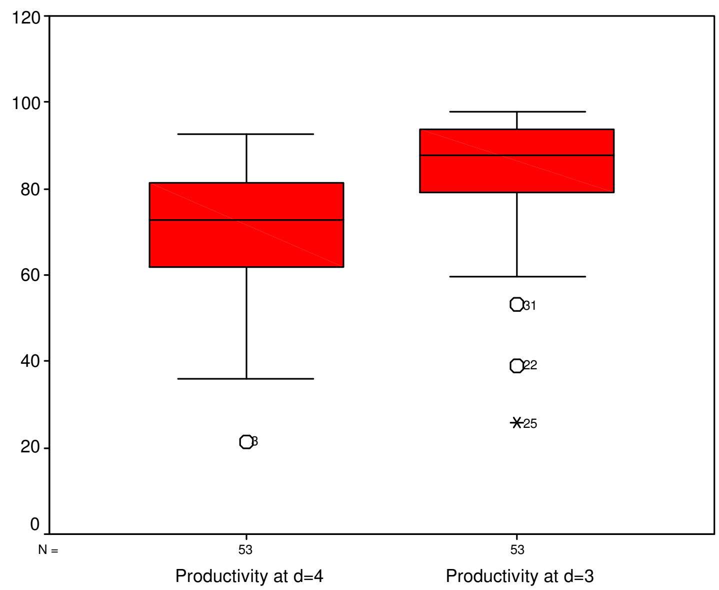

Figure 7-32 Box plot of productiveness at different depths

	Paired Diifferences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	97.5% Confidence Interval of the Difference Lower	Upper			
Productivity of linear menu at d=4- Productivity of linear menu at d=3	-12.8955	17.04379	2.34115	-18.2993	-7.4918	-5.508	52	.000

Table 7-17 t-test of significance for productivity at different depths

As shown in Table 7-17, t- Statistics confirms significance of differences in values (t_{52} = -5.508, p<. 025). Negative value of t indicates the direction in which mean value is smaller. In this case mean productivity of users in linear menu at depth d=4 is significantly lower than that of at d=3. Henceforth we can reject our null hypothesis, which states that $\rho_3 = \rho_4$. A box plot of distribution is visualized in figure 7-32 to assess the difference in two values.

Above results and test of significance all together confirms our alternative hypothesis that Productivity of users at d=3 is higher than productivity of users at menu depth d= 4 i.e. $\rho_3 > \rho_4$. Additionally a Wilcoxon Signed Rank test was performed which also confirms that only 9 cases of productivity at depth 3(Z_9= -4.652, p<. 025) are higher than that of at depth 4, whereas 44 cases found positively ranked and signifies that $\rho_3 > \rho_4$.

Result review:

1. The significance value for productivity at depth d=4 (Z_{53}= 0.835, p= 0.489) and at depth d=3 (Z_{53}=1.240, p=0.092) resembles that the distribution of productivity at menu depth of 3 as well as of 4 are normally distributed.

2. t-test confirmed that, at changed depth a significant difference (t_{52} = -5.508, p<.025) in efficiency exists. Henceforth we can reject our null hypothesis of equal productivity (ρ_3: Mean=83.66, SD= 14.72; ρ_4: Mean= 70.76, SD=15.71)

3. Wilcoxon Signed Ranks test confirms that ρ_3 is significantly greater in 44 cases as compared to 9 of ρ_4 (Z_9= -4.652, p<. 025), which is almost five times and we can conclude $\rho_3 > \rho_4$.

7.3 Discussion

The study shows that there could be substantial performance differences depending on the interface menu technique used on the small-screen system. In particular, linear menu structure with minimum depth was significantly efficient than the menu with higher depth. In this part, the task, which involved only 3 level of menu depth, was found more productive than the task with one additional level of menu depth. In this section of our hypothesis, we tested only linear menu with depth variations, the same task was given to participants in non-linear menu but from the design point of view it did not allowed depth variations. In future research one can explore how the overall productivity of both kind of menu structures vary with respect to each other. Efficiency of a menu as we defined it in methodology chapter is a term, which is to be measured in terms of steps involved to complete a particular task. Design and implementation of linear menu is always common to sub group the options in a logical manner. It increases sometimes the depth of menu in particular where the screen size is small. We have observed it in our study, as soon as users made a mistake in 3rd level menu, they were bound to repeat the steps performed once again- which in turn increased the total steps taken to complete the task and finally resulted into poor efficiency.

Productivity of a menu is measured in terms of time. However if a user took more steps to complete the task, he took more time and which reduces productivity. It has been frequently observed that many users found difficulty to locate the menu on selection item. Sometimes they found lost and quite irritated. However proper explanation and exercise time has been provided to be confident with simulated environment, they tried to work as in case of large screen applications. A limited screen size and available options were clearly visible, but many users were frequently stopped during the task operation. 13 users had asked for a key to 'enter' (as in case of desktop keyboard) whereas many users asked for a 'button' e.g. to 'save' the task at the end of completion. To ask for an 'enter' key is somewhat related to repetitive use of large screen computers but to ask for a 'button' on screen seems here to be interesting from research point of view. It shows a clean demand of something laid spatially on available screen. There may be possibility that users have tendency to select from a list, but to confirm they expect a confirmation command button on the screen itself.

Small font size and minimum space available for selection caused another problem to users. Set pattern of using mouse in large screen allows users to move hands with greater degree of freedom, it has been observed that initially users were moving hands on small screen as in case of traditional computers, which resulted into chaotic selection of menu options. In future, instead of using simulated environment, these tests can be performed in real PDAs and results can be compared.

In the following paragraphs, we consider explanations for these results, and discuss how our findings generalise.

The generality of our results can be considered in terms of the tasks, the implementation of the techniques, and the physical characteristics of real small-screen devices. The practicality of our study task provides good evidence that the results can be generalised to real-life situations where people are familiar with the large interface. The editing and navigating tasks in particular already involve real applications, real data, and a large subset of the interactions that will occur in most applications. There may be additional differences, however, in tasks that involve other interaction styles (e.g. reading of text, visual search). Although we believe that the differences between the individual techniques will also be apparent in other situations, it is possible that changing the way that the techniques were implemented could reduce these differences. For example, use of non-linear menu can be improved by coupling with some sub set of linear menu.

Finally, there are various limitations in the physical devices themselves that may affect the pattern of menu uses. For example, in some stylus-based systems, there is no notion of moving the pointer without dragging; because the screen cannot detect the stylus unless it is pressed onto the screen, (others detect the stylus a few centimetres away). A simulated environment, however tried to make as realistic as possible, it cannot be compared to the device in hand itself. The effect of pointing device has also an impact on the user's performance with the device. People from different background may have some other style to operate on small screen devices e.g., painter can use their finger in some other way than a car mechanic.

However it has been tried to minimise the effect of external factors (as described above) in simulated device, test persons have frequently performed as in case of desktop application (e.g. mice movement).

Menu design is also as a limitation observed; in our prototype, hierarchical linear menu is used. The menu design needs to be further explored. There may be better menu designs than the hierarchical we used in case of linear menu.

Overall, abstaining from these micro effective factors, a normal trend that user's performance decrement with menu depth has been recorded.

Chapter 8

Summary

This chapter summarises the previous chapters that discussed various aspects of Interface complexities. On the one hand, this thesis shows comparison of linear and non-linear menu on the other hand, it concludes that many improvements can still be made. The hand-held PDA is a valuable platform for providing modelling and simulation results to users in the field. The computing capabilities and display size require the software developer to design carefully the application to minimize the amount of user input and data presentation. Nevertheless, there are numerous applications, which are suitable for PDAs; the emergence of wireless networking, better displays, and increased computational power will further expand these opportunities.

We first summarise the work and state the main contributions of this thesis.

8.1 Summary of thesis

In the introduction section of this thesis, we have reviewed a number of literatures concerned to the problem associated with in a computing device. We have identified there were mainly three areas of interest viz. Psychology of human being, human-computer-interaction and human-computer- interaction with mobile devices. It was found that work and occupational psychology found appropriate to employ the concept of man-technology–organisation. We came across through various approaches such us socio technical implication and user centeredness. Human – computer- Interaction perspective found that Designing user interface for small screen is a difficult problem, much more difficult than it may seem at first glance. Mobile HCI has to do with the usability of application, about the user interfaces, control of the device, visual representation, ergonomics, context awareness, interaction and navigational issues etc.

We have investigated interface complexity- status of Personal digital assistants in this study, user interfaces are primarily considered as the display content of the available screen. User interface of the small handhelds is an important and rather unavoidable area of research. User interaction problem identified within the menu selection can be viewed as problem of option availability. Past years theses ideas have become central to various design methodologies, ranging from the socio-technique, user centred design, user-involved design, and more recently, computer supported cooperative working. It has been found that, social compatibility of a technology and their implications to MTO indicates towards a state where, organisation sets up task priority, while human requires easiness to perform these tasks. Therefore, the achievement of socially compatible technology can be made possible through the design of these technologies through human centeredness. Hence, the identification of relevant user interface properties is to be checked. Overall, it can be summarised that, research on alternative menu (non-linear) and comparison with linear menu in modern handhelds are then valuable and significant.

In the second chapter, we have discussed about handheld devices and their available configuration. We have discussed its significance and portability and tried to find an acceptable definition of handhelds. We found that problem of user interface arise due to complex nature of computing principle running behind the application. In the same way, PDAs are consisting of hardware and embedded/ operating software, which force one to understand user interface in two different dimensions: hardware interface and software interface. A classification of PDA user interface has been developed.

In chapter 3, we found that there is less standardization in hardware supporting menu traversal for PDAs than for desktop machines. However, the organization of menu has an effect on performance. All theses discussion demonstrated that handheld have considerably small screen size and this small screen size do have an impact on user's performance. One cannot rule out the demand of restructuring menu interfaces and need to rethink on interface design possibilities for small screen sized devices. Apart of these interventions of man-technology-organisation theory applied to contextual use of ever becoming small devices.

Chapter 4 is dedicated to the theoretical background knowledge on the research topic. We have defined the user, interface and usability of interfaces etc. It is found that interface design is a method for designing complex interactive systems. Such systems are characterized by having several kinds of users and other stakeholders that are all involved with the system. Designing such a system is a difficult task and our design method is intended to handle such cases. In task-based design, quality is defined as a high level of usability. Usability is a complex concept and has many often-confusing interpretations. We have also discussed the linearity and non-linearity of menu. Finally, we have explained complexity of user interface and fixed relevant measurable parameters. We found that complexity is merely and approximation but real problem and need to be solved. We found that complexity is to be understood in terms of satisfaction, effectiveness and efficiency of users and menu both.

Chapter 5 describes the hypothesis made before research, in terms of complexity of menu interfaces we hypothesised if the non-linear menu is better than linear menu and whether the menu depth is co-related to Users performance. Based on the theory explained in chapter 4, we also hypothesised that non-linear menu may be better suited to the technicians working in a specific organisational set-up.

Chapter 6 discuses the methodological approach to be followed for proposed research. It was required to adopt different methodologies for various stages of study. Study methodology was discussed and we found laboratory experiment coupled with applied research technique is appropriate. Measurement methodology was then discussed and we found, certain measurement metrics suitable to quantify the abstract parameters fixed at study phase. Mainly three types of performance metrics have been used to predict the complexity of menu. These are satisfaction score, time and error rate. Efficiency and productiveness has been used to predict performance of users and menu both. Since there is little work done on the small screen interfaces, we have extracted some fundamental concepts of information science to apply in our research. For evaluation and statistical interpretation of hypothesis (hypothesis testing), we found deductive- hypothetical approach more appropriate for the study.

Chapter 7 describes evaluation and results explanation. While doing statistical analysis both art of menu were tested against satisfaction score, time taken, steps required and error committed to perform a task. It was analysed that if non-linear menu is better suited for technicians to reach the conclusion whether MTO has a relevant effect on the user interface. Results are summarised in the following section. Finally, along with future research possibilities conclusive statement has been drawn in chapter 9.

8.2 Summary of results

Principle results are summarised in tabular form resulted from SPSS output table:

Report

Profession		Satisfaction score of Linear Menu	Satisfaction score of Non-Linear menu	Time taken in linear menu	Time taken in non-linear menu
Student	Mean	111.38	127.73	233.808	129.658
	Std. Deviation	15.528	12.457	63.5875	37.4223
Technician	Mean	102.59	125.15	244.789	129.993
	Std. Deviation	20.315	18.522	72.5761	20.3639
Total	Mean	**106.91**	**126.42**	**239.402**	**129.828**
	Std. Deviation	18.492	15.742	67.8844	29.6758

Table 8.1 Summary of satisfaction score and time taken (in seconds) among students and technicians

Report

Profession		Steps taken in linear menu	Steps taken in non-linear menu	Error made in linear menu	Error made in in non-linear menu
Student	Mean	34.85	15.81	14.00	4.81
	Std. Deviation	11.274	6.951	10.602	6.951
Technician	Mean	39.22	14.63	19.22	3.04
	Std. Deviation	12.160	3.410	12.160	3.044
Total	Mean	**37.08**	**15.21**	**16.66**	**3.91**
	Std. Deviation	11.829	5.422	11.616	5.354

Table 8.2 Summary of steps taken and error made among students and technicians

Report

Profession		Eff. at d=3	Eff. at d=4	Productivity at d=3	Productivity at d=4
Student	Mean	65.9990	56.4091	86.2417	72.0886
	Std. Deviation	28.60168	23.86335	12.47446	15.08081
Technician	Mean	68.3993	43.4093	81.1749	69.4903
	Std. Deviation	22.86005	19.08377	16.45263	16.48086
Total	Mean	**67.2218**	**49.7866**	**83.6605**	**70.7649**
	Std. Deviation	25.61356	22.33649	14.72063	15.71212

Table 8.3 Summary of efficiency (%) and productivity (%) in linear menu at depth d= 3 and at d=4

Case Summaries

Age	Sex		Satisfaction score of linear menu	Satisfaction score of non-linear menu	Time taken in linear menu	Time taken in non-linear menu	Steps taken to complete tasks in linear menu	Steps taken in non-linear menu	Error made in linear menu	Error made in non-linear menu
>20	Female	Mean								
		Std. Deviation								
	Male	Mean	113.25	131.25	220.050	132.650	34.50	15.25	14.50	1.50
		Std. Deviation	14.056	15.521	44.5676	29.9846	7.767	5.315	7.767	1.291
	Total	Mean	**113.25**	**131.25**	**220.050**	**132.650**	**34.50**	**15.25**	**14.50**	**1.50**
		Std. Deviation	**14.056**	**15.521**	**44.5676**	**29.9846**	**7.767**	**5.315**	**7.767**	**1.291**
21-35	Female	Mean	104.89	127.79	225.468	126.911	35.53	15.63	14.89	4.63
		Std. Deviation	18.315	9.319	58.6219	36.9280	11.867	7.236	11.289	7.236
	Male	Mean	112.20	120.60	253.900	137.307	37.80	16.20	17.13	4.87
		Std. Deviation	20.946	22.500	86.8833	29.3356	13.940	4.960	13.820	5.139
	Total	Mean	**108.12**	**124.62**	**238.012**	**131.497**	**36.53**	**15.88**	**15.88**	**4.74**
		Std. Deviation	**19.562**	**16.591**	**72.6793**	**33.7101**	**12.671**	**6.251**	**12.321**	**6.307**
36-50	Female	Mean								
		Std. Deviation								
	Male	Mean	101.36	127.09	224.436	125.718	34.55	13.64	14.55	2.64
		Std. Deviation	18.397	15.215	45.8780	22.2748	5.538	2.767	5.538	2.767
	Total	Mean	**101.36**	**127.09**	**224.436**	**125.718**	**34.55**	**13.64**	**14.55**	**2.64**
		Std. Deviation	**18.397**	**15.215**	**45.8780**	**22.2748**	**5.538**	**2.767**	**5.538**	**2.767**
51-65	Female	Mean								
		Std. Deviation								
	Male	Mean	101.00	133.33	297.533	125.700	49.67	14.67	29.67	3.67
		Std. Deviation	13.748	10.693	73.9668	9.0205	16.563	2.887	16.563	2.887
	Total	Mean	**101.00**	**133.33**	**297.533**	**125.700**	**49.67**	**14.67**	**29.67**	**3.67**
		Std. Deviation	**13.748**	**10.693**	**73.9668**	**9.0205**	**16.563**	**2.887**	**16.563**	**2.887**
<65	Female	Mean								
		Std. Deviation								
	Male	Mean	119.00	140.00	354.300	119.400	56.00	11.00	36.00	.00
		Std. Deviation	.	.	.	.	.	.	.	.
	Total	Mean	**119.00**	**140.00**	**354.300**	**119.400**	**56.00**	**11.00**	**36.00**	**.00**
		Std. Deviation	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**.**
Total	Female	Mean	**104.89**	**127.79**	**225.468**	**126.911**	**35.53**	**15.63**	**14.89**	**4.63**
		Std. Deviation	**18.315**	**9.319**	**58.6219**	**36.9280**	**11.867**	**7.236**	**11.289**	**7.236**
	Male	Mean	**108.03**	**125.65**	**247.188**	**131.459**	**37.94**	**14.97**	**17.65**	**3.50**
		Std. Deviation	**18.769**	**18.478**	**72.2000**	**25.2237**	**11.896**	**4.196**	**11.845**	**4.017**
	Total	Mean	**106.91**	**126.42**	**239.402**	**129.828**	**37.08**	**15.21**	**16.66**	**3.91**
		Std. Deviation	**18.492**	**15.742**	**67.8844**	**29.6758**	**11.829**	**5.422**	**11.616**	**5.354**

Chapter 9

Conclusions

User interface for mobile devices has not been a major research topic in the past. It is therefore necessary to set up research to lay the foundations for "good" user interface for this class of devices. In the previous, more emphasis has been given to contextual use, personalisation, services and interoperability of the device; whereas basic functional features such as menu pattern in such a small screen is forgotten. It is repeatedly spoken about the small screen size as major problem causing interaction difficulty. However, it is true, that the small physical size of a PDA limits the maximum size of its screen, but it is also true that it can be no larger than the dimensions of the machine in which it is embedded. It is not much possible to increase the physical size of device hence small screen of the display. In this situation, one has to develop some other form of interaction for the screen layout so that it appears less complex to the user.

In our study we believed, linear structure of menu arrangement for PDA small screen could be inappropriate and makes the interface complex for the user. While reviewing a number of literatures, we also found that interface and interaction principle for PDA were directly translated from their desktop counterpart. Providing linear menu for PDA is common. We have rejected this trend for our study and proposed a non-linear set of menu for small screen of PDA. The objective was to clarify empirically that non-linear structure is less complex while measured in terms of user's satisfaction, time, error, efficiency and productiveness. We also hypothesised that, an interface may be complex for certain task and for certain segment of user. Therefore, we believed that non-linear set of menu can be easier for industrial technicians and therefore can be efficiently used in those organizations (MTO- intervention). In all the result of study can be concluded as described in following paragraphs.

1. To decide the interface complexity we have fixed three parameters viz. satisfaction rating given by user, time to task completion, and error committed. We have found that linearly arranged menu found to be more difficult than non-linearly arranged menu. Users preferred non-linear menu with 126.42 points (N= 53, SD=

15.74) compared to 106.9 points given for linear menu (N=53, SD= 18.42). This trend was similar for both the control groups i.e. students and technicians. Students have given an average point 111.38 (N= 26, SD=15.529) and technicians 102.59 (N=27, SD= 20.31) to linear menu. Comparing two groups we found that technicians rating was less for linear menu than students were, but in case of non-linear menu i.e. technicians have given almost same 125.15 (N=27, SD=18.52) as students 127.73 (N=26, SD= 12.45). Based on these finding, it cannot be concluded that particularly technicians preferred non-linear menu significantly more than students did. A general trend implies that ***non-linear menu resulted more satisfaction*** to the user. The task were defined in such a way that they suited to technicians daily routine work , results shows that nature of task does not have significant effect in case of non-linear menu i.e. it is irrelevant which work background they are coming from, their rating is almost same. Nevertheless, it has an effect in case of linear menu, as technicians preferred less. One explanation might be due to fact that non-linearly arranged menu is relatively more suited for technicians and we can draw conclusion in a way that though non-linear menu is equally preferred by both the groups, linear menu is considerably less preferred by technicians. Technicians have given 22 % more point to non- linear menu whereas non-technicians only 14.7 % more as compared to linear menu. In other words, if technicians have choice to use menu, they will prefer non-linear as compared to linear menu.

2. We believed that personal liking and disliking is rather very subjective and it is required to validate by considering other measurable parameters. One important aspect is time taken to complete the task. We have observed that users have taken 239.40 s (N=53, SD= 67.88) to complete the task in linear menu more than 129.82 s (N=53, SD=29.67) in case of non-linear menu. It is quite noticeable that time taken to complete the same task in non-linear menu is almost half than that of linear menu. However, group difference of subjects showing no significant difference in case of non-linear menu (Students: 129.65 s, N=26, SD= 27.42; Technicians: 129.99 s, N=27, SD= 20.36). Technicians are taking more time (244.78 s, SD= 72.57) as compared to students (233.80 s, SD= 63.58) to complete the task in case of linear menu. As far as the time taken to complete the task is concerned it can not be concluded that technicians are better in case of non-linear menu, however they took more time in case of linear menu. General comparison of task completion time indicates that

technicians are taking 88 % (which is above the average 84 % of all users) time in linear menu as compared to non-linear menu whereas non-technicians are taking 80% (average 114 s) more time to complete the tasks in linear menu. If we consider this 8% difference in task completion time, we can conclude that non-linear menu is rather better suited for technicians.

The same happens with other two parameters i.e. steps taken and error committed. Users have taken an average of 37.08 steps (N=53, SD= 11.82) in case of linear menu more than double of non-linear menu 15.21 (N=53, SD=5.44). Error rate was much higher in case of linear menu 16.66 (N=53, SD=11.61) compared to 3.91(N=53, SD=5.35) in case of non-linear menu.

Technicians have committed 532 % (average 16) more error in linear menu as compare to non-linear menu where as non-technicians committed only 191 % (average 9) more error in case of linear menu. This indicates that there is a difference of approximately 450% between technicians and non-technicians to commit error in linear menu. This finding shows clearly that technicians are much likely to commit errors while performing tasks in linear menu. As far as steps taken to complete the tasks are concerned non-technicians have taken 120% (average 19) more steps in linear menu where as technicians have taken 168 % (average 25) more steps to complete tasks in linear menu as compared to non-linear menu. These results altogether validating the outcome that linear menu is less preferred, consuming more time and having higher error probability than non-linear menu. A Comparison graphical presentation of summary is as shown in figure 9-1, 9-2 and 9-3.

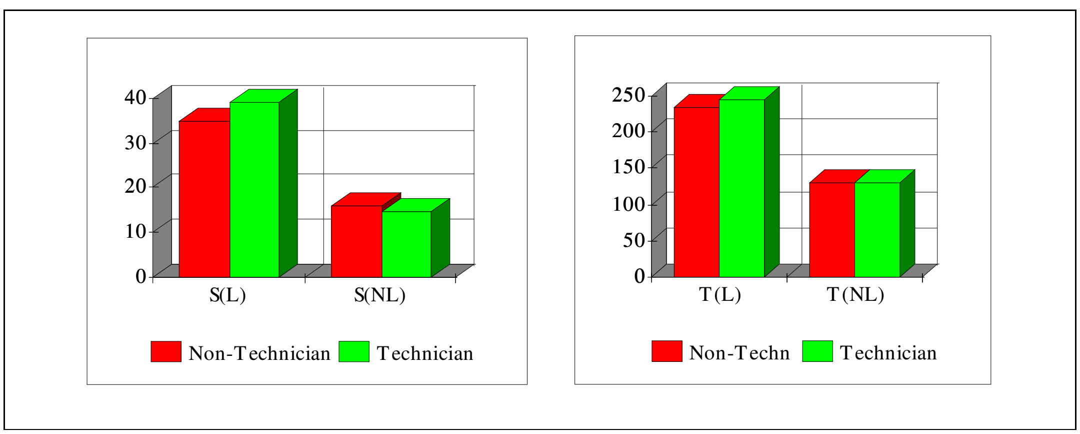

Figure 9-1 Comparison summary of steps taken and time taken

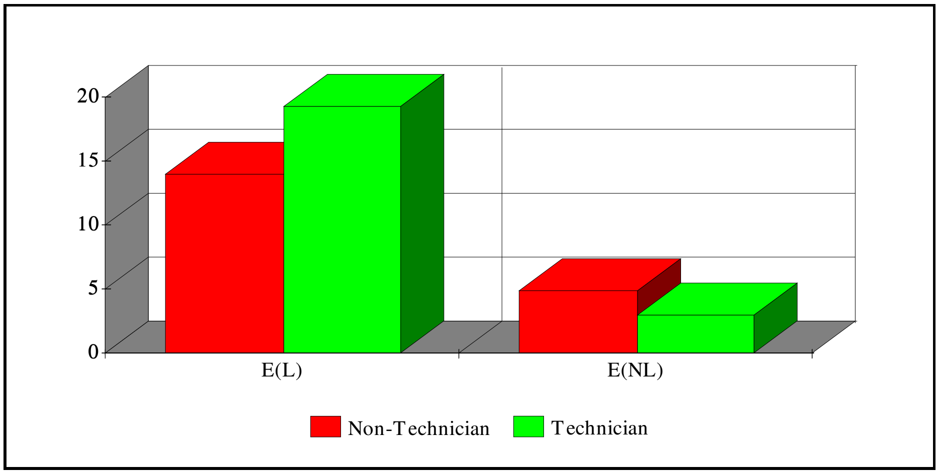

Figure 9-2 Comparison summary of error committed

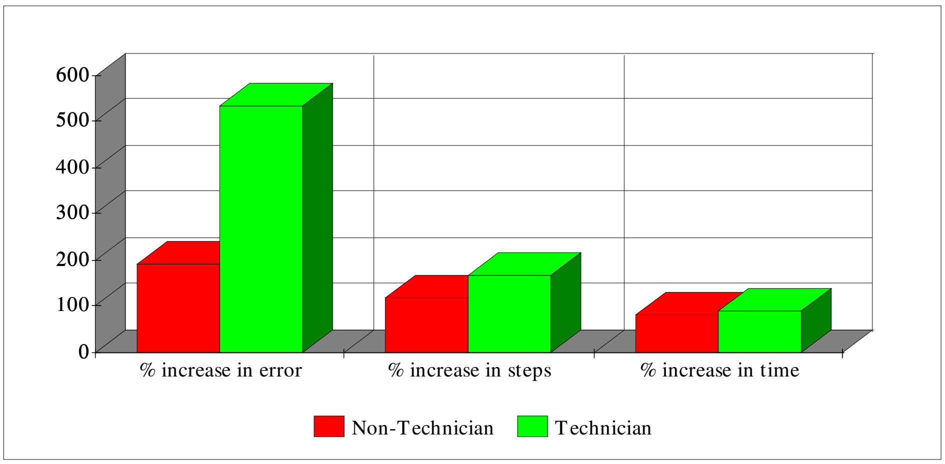

Figure 9-3 % increase of error, steps and time in linear menu with respect to non linear menu

3. While testing our null hypothesis of equal satisfaction score mean, we found there is significant difference and rejected it, further alternative hypothesis is being tested to see if satisfaction score of no-linear menu is significantly more. The descriptive analysis of data validate our alternate hypothesis and clearly indicate that there is change in satisfaction score of two menus [mean SS_L =106.9, mean SS_{NL}= 126.4 ($SS_L < SS_{NL}$)].

Similarly, paired sample t- test indicates that mean error rate in linear menu and non-linear menu are significantly different ($E_L \neq E_{NL}$), which was further confirmed by descriptive statistical analysis that, there were 49 cases (N=53) in which total error committed in non-linear menu were less than linear menu. As far as task completion time is concerned, paired sample t-test of time taken to finish the task showed significant difference (t_{52}= 11.785, $p < 0.001$) between linear and non-linear menu, which was also further confirmed in alternate hypothesis testing that mean time taken to complete the task in linear menu (M=239.402, SD=67.88) is significantly more than mean time taken to complete the task in non-linear menu (M= 129.828, SD =29.67).

In view of above results, we can conclude that Non-linear menu structure decreases interface complexity in small screen display interfaces and that non-linear menu are better suited for technicians in some extent as compared to linear menu. However, we cannot generalize this conclusion specifically, only for technicians as; we found in-general non-linear menu was better suited for other users as well.

Our second hypothesis testing menu depth variation in linear menu confirms that, at changed depth a significant difference (t_{52} = -3.702, $p< .005$) in efficiency exists at different depth level (at d=3: Mean efficiency = 67.22, S.D = 25.61; at d=4: Mean efficiency = 49.78, S.D = 22.33). More precisely, efficiency at 3rd was found significantly higher in 37 cases as compared to only 16 cases at 4th level. Similarly mean value of productivity of users at different depths, at d=3 (Mean= 83.66, SD= 14.72) is higher than productivity at d=4 (Mean =70.76, SD= 15.71). Henceforth we can reject our null hypothesis of equal efficiencies and productivity and confirm our second hypothesis as menu depth in linear menu increases user's performance decreases. In fact, this conclusion provides a validation and at least one cause to hold our first hypothesis. So that we can say, due to increased depth level involved in linearly arranged menu, there may be possibility of increase in complexity of operation. Nevertheless, there may be other possible reasons and causes involved and need to be explored in future research.

Academic contribution, practical Implication & suggestions for future research

Since the field of user interface design is still developing rapidly, we discuss some ideas for future research on interface design in particular menu organisation issues.

Developing a new method to design menu should be done further, there are still many areas that need to be improved both on the theoretical as the practical side. Theories are important to link together many aspects in the process of design. With the help of sound theories, we can develop practical techniques that make improvements. Many techniques are also developed; we have tried here an alternate menu structure and let it empirically clarified, studying them can also contribute much to theoretical understanding.

This thesis discusses interaction design patterns as a promising technique to incorporate explicit design knowledge into the design process. We feel that this is just the start of a promising research area. User interfaces are composed of many elements that are put into a specific structure. Patterns are a means to try to understand why some arrangements of elements are better than others and under which circumstances. This is exactly the kind of knowledge, which gives designers a better understanding of their tools of the trade so they will get better at using them. In order to make user interface design more of a human- engineering discipline, it needs to excel in analysing the problem well and creating solutions using valuable design knowledge.

In modern times, what we experiencing is a trend to access things or articles that are small and handy to operate. It is forecasted that in future things, which are small and oval, will attract more to the people (consumers). Popularity of cell phone across the globe is one example. Technology is advancing day by day and feeding product developer much challenge, alone this will not proved sustainable until human-technology and society finds themselves in a state to utilise usefully these tools. The present thesis recognises importance of small screen devices in relation to human and organisation at other ends. The discussions, which we made and the idea we applied are of not less value, if they can accelerate the academic community to think more sensibly for small screen device especially for their user interface.

When we thought about applying principle of non-linearity in user interface, it was rather based on a practical experience of human use behaviour. Women's often think in a non-linear way, men are in contrast- linear. Linearity is closely related to a systematic arrangement (i.e. one after another) where as non-linearity what is distributed (or chaotic- if not unsystematic). One asks men to get a hammer let them think linear that hammer belongs to repair work commonly placed in tool box, which is to find nearby auto board in basement. If by chance one forgets to place hammer in toolbox, it is easily recognisable to get it again in a big house. The reason is missing an item in linear arrangement break the whole chain, the one start to search it everywhere (non-linear). Women are more efficient in finding the things, may be due to the fact of having non-linear kind of arranging the things in their mind. Anyway, what we want to say is in some cases chaotic arrangement facilitates easiness if they are systematically arranged. We have applied this principle to menu arrangement, and believe that a more refined and detailed research let it mathematically formulated to get a defined set of rule in case of non-linear menu. The current thesis is one-step forward to contribute in research of user interface for mobile devices.

During the course of planning, designing, testing and evaluating the current research, we felt a numerous restrictions, limitations and some times other related ideas (when we thought: if that could also be done!). Due to a definite shape of a doctoral thesis and its accuracy, however, it was not possible. Still we feel that these limitations, restrictions and ideas may further help other researcher to go forward. Variation in task background and users from other professional background can help to get result, if particular kind of menu is especially well suited to the users of particular professional background. As in our case, we have seen a normal trend that non-linear menu sounds to better than linear menu, but we cannot make clear distinction that especially well suited to technicians only. We have applied only hierarchical set of linear menu, there must be other art of linear menu (sequential, simultaneous etc) tested against non-linear menu to get results that are more accurate and to generalise the findings. Intercultural effect on menu use pattern may help further to universalise the result. Use pattern of information devices are differing across the continent as well nations, e.g. in Japan, people are more comfortable in working with small devices (one possible reason is may be due to their small fingers!). In addition, we have used a simulated environment; a real field test with device can be used to cumulate the results. As stated above, a mathematically significant formula can be develop to decide no. of item places in one screen and the no. of dependent sub items it can represent in same fashion.

In short, innovative, promising, interesting but ever becoming *small* field of PDA like devices left us to do *big* things.

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Appendix A

Statistical data in SPSS

	subject	age	sex	prof	ltask1	ltask2	ltask3	ltask	ltotal	nltask1	nltask2	nltask3	nltask	nltotal
1	S1	21-35	Femal	Technician	14	6	24	18	62	27	19	30	44	120
2	S2	21-35	Male	Technician	24	9	22	40	95	30	20	30	48	128
3	S3	21-35	Femal	Student	18	20	21	46	105	30	27	30	50	137
4	S4	<65	Male	Student	17	26	26	50	119	30	30	30	50	140
5	S5	36-50	Male	Technician	12	19	20	24	75	30	22	23	48	123
6	S6	36-50	Male	Technician	18	16	18	32	84	25	17	24	36	102
7	S7	36-50	Male	Student	17	15	23	30	85	25	30	24	40	119
8	S8	21-35	Femal	Technician	13	24	27	40	104	26	26	29	48	129
9	S9	21-35	Male	Technician	10	13	13	12	48	12	11	13	22	58
10	S10	21-35	Male	Student	25	27	25	48	125	30	30	24	50	134
11	S11	21-35	Male	Student	19	30	27	50	126	18	26	30	50	124
12	S12	21-35	Femal	Student	25	30	30	48	133	28	23	27	50	128
13	S13	21-35	Femal	Student	26	21	30	48	125	28	26	17	42	113
14	S14	36-50	Male	Technician	17	28	26	44	115	30	30	23	44	127
15	S15	21-35	Male	Student	23	30	30	46	129	16	22	19	28	85
16	S16	21-35	Male	Student	23	21	28	48	120	29	30	30	50	139
17	S17	21-35	Male	Student	21	30	28	44	123	30	24	30	48	132
18	S18	21-35	Male	Student	22	12	30	42	106	27	30	30	42	129
19	S19	21-35	Femal	Student	20	13	30	32	95	30	30	27	50	137
20	S20	21-35	Femal	Student	20	25	30	44	119	30	30	30	50	140
21	S21	21-35	Male	Technician	26	29	28	48	131	25	30	17	40	112
22	S22	21-35	Femal	Technician	22	27	19	44	112	29	19	27	44	119
23	S23	21-35	Male	Technician	28	17	30	38	113	30	30	30	50	140
24	S24	21-35	Male	Student	26	26	26	44	122	25	24	26	36	111
25	S25	21-35	Femal	Technician	19	23	23	34	99	26	29	18	42	115
26	S26	21-35	Male	Student	18	28	23	39	108	30	30	28	44	132
27	S27	21-35	Femal	Student	21	29	30	36	116	24	28	17	44	113
28	S28	21-35	Femal	Student	25	30	26	40	121	28	30	28	50	136
29	S29	21-35	Femal	Student	14	13	19	34	80	30	24	30	50	134
30	S30	21-35	Male	Student	25	30	30	34	119	30	29	23	46	128
31	S31	21-35	Female	Student	10	20	22	32	84	19	25	27	42	113
32	S33	21-35	Female	Student	17	23	28	28	96	10	29	28	46	130
33	S34	21-35	Female	Student	23	25	30	48	126	30	26	30	50	136
34	S35	21-35	Male	Student	20	26	26	50	122	30	30	30	50	140
35	S32	21-35	Female	Student	15	25	27	24	91	25	28	28	50	131
36	S36	21-35	Female	Student	17	27	21	30	95	29	25	27	48	129
37	S37	21-35	Female	Student	22	26	20	38	106	26	30	25	50	131
38	S38	51-65	Male	Technician	21	18	26	48	113	30	30	29	50	139
39	S39	36-50	Male	Technician	13	21	22	32	88	25	14	25	34	98
40	S40	36-50	Male	Technician	16	22	26	30	94	30	27	30	50	137
41	S41	51-65	Male	Technician	19	30	17	38	104	30	30	30	50	140
42	S42	36-50	Male	Technician	18	20	30	44	112	30	30	30	50	140
43	S43	36-50	Male	Technician	23	22	22	36	103	26	30	30	50	136
44	S44	36-50	Male	Technician	19	22	23	36	100	28	28	30	50	136
45	S45	36-50	Male	Technician	27	26	26	50	129	30	30	30	50	140
46	S46	36-50	Male	Technician	22	30	30	48	130	30	30	30	50	140
47	S47	21-35	Female	Technician	23	26	25	50	124	30	30	29	48	137
48	S48	51-65	Male	Technician	15	23	16	32	86	30	30	19	42	121
49	S49	21-35	Male	Technician	19	23	22	32	96	26	23	26	42	117
50	S50	>20	Male	Technician	26	28	27	50	131	30	30	30	50	140
51	S51	>20	Male	Technician	21	26	21	42	110	26	16	28	38	108
52	S52	>20	Male	Technician	26	23	24	42	115	30	30	29	50	139
53	S53	>20	Male	Technician	17	24	24	32	97	30	30	30	48	138

ltask1= satisfaction score/task1/ linear menu
ltask2= satisfaction score/task2/ linear menu
ltask3= satisfaction score/task3/ linear menu
ltask= satisfaction score/ end / linear menu
ltotal= satisfaction score of linear menu

nltasl1= satisfaction score/task1/ non-linear menu
nltask2= satisfaction score/task2/ non-linear menu
nltask3= satisfaction score/task3/non- linear menu
nltask= satisfaction score/end / non-linear menu
nltotal= satisfaction score of non-linear menu

	lt1	t1p	prt1	lt2	t2p	prt2	lt3	t3p	prt3	lttotal	lt_real	prl
1	124.7	347.0	35.94	110	125	87.84	57.4	79.0	72.7	291.9	328.2	88.94
2	90.4	111.0	81.44	246	255	96.35	175	181	96.9	511.4	546.1	93.65
3	77.3	360.0	21.47	39.3	41.0	95.85	55.2	106	52.1	171.8	207.6	82.76
4	238.3	312.0	76.38	44.9	50.0	89.80	71.1	92.0	77.3	354.3	454.0	78.04
5	99.0	107.0	92.52	75.0	81.0	92.59	68.6	78.0	87.9	242.6	251.2	96.58
6	72.2	175.0	41.26	40.6	54.0	75.19	50.9	72.0	70.7	163.7	197.7	82.80
7	87.5	124.0	70.56	57.4	76.0	75.53	59.4	62.0	95.8	204.3	242.0	84.42
8	121.0	191.0	63.35	47.5	57.0	83.33	53.0	84.0	63.1	221.5	277.0	79.96
9	125.0	163.0	76.69	46.4	55.0	84.36	52.4	59.0	88.8	223.8	255.0	87.76
10	150.1	179.0	83.85	44.6	47.0	94.89	64.8	72.0	90.0	259.5	296.0	87.67
11	81.4	100.0	81.40	31.6	34.0	92.94	47.6	53.0	89.8	160.6	187.0	85.88
12	139.0	186.0	74.73	34.9	37.0	94.32	49.9	59.0	84.6	245.8	282.0	87.16
13	107.9	157.0	68.73	116	120	96.92	64.9	73.0	88.9	289.1	303.0	95.41
14	141.5	231.0	61.26	50.9	61.0	83.44	79.6	87.0	91.5	272.0	298.0	91.28
15	257.2	287.0	89.62	35.6	38.0	93.68	69.3	75.0	92.4	362.1	396.0	91.44
16	83.6	110.0	76.00	115	117	97.95	64.5	75.0	86.0	262.7	302.0	86.99
17	79.7	98.00	81.33	104	106	97.74	63.3	72.0	87.9	246.6	276.0	89.35
18	81.6	105.0	77.71	31.6	34.0	92.94	65.4	72.0	90.8	178.6	211.0	84.64
19	66.4	94.00	70.64	18.6	27.0	68.89	55.4	58.0	95.5	140.4	171.0	82.11
20	102.3	122.0	83.85	98.0	104	94.23	73.1	94.0	77.8	273.4	307.0	89.06
21	94.8	136.0	69.71	30.6	34.0	90.00	71.7	96.0	74.7	197.1	228.0	86.45
22	139.4	231.0	60.35	26.6	68.0	39.12	62.7	136	46.1	228.7	262.0	87.29
23	83.5	126.0	66.27	46.6	57.0	81.75	131	139	94.1	260.9	296.0	88.14
24	125.1	207.0	60.43	45.0	52.0	86.54	52.4	70.0	74.9	224.1	255.0	87.88
25	153.1	294.0	52.07	51.6	200	25.80	65.4	93.0	70.3	270.1	301.0	89.73
26	139.3	231.0	60.30	39.6	49.0	80.82	54.3	97.0	56.0	233.2	256.7	90.85
27	70.9	100.0	70.90	47.6	50.0	95.20	49.3	55.0	89.6	167.8	205.0	81.85
28	156.4	240.0	65.17	47.6	58.0	82.07	45.4	107	42.4	249.4	277.0	90.04
29	100.1	126.0	79.44	26.9	45.0	59.78	50.2	88.0	57.0	177.2	215.0	82.42
30	139.4	165.0	84.48	98.5	105	93.81	49.6	59.0	84.1	287.5	325.0	88.46
31	108.2	175.0	61.83	26.6	50.0	53.20	62.8	72.0	87.2	197.6	242.0	81.65
32	186.9	210.0	89.00	82.7	86.0	96.16	83.0	89.0	93.3	352.6	385.0	91.58
33	62.9	128.0	49.14	42.3	48.0	88.13	55.6	57.0	97.5	160.8	198.0	81.21
34	125.9	167.0	75.39	22.9	29.0	78.97	70.6	78.0	90.5	219.4	244.0	89.92
35	66.4	128.0	51.88	18.6	29.0	64.14	55.4	58.0	95.5	140.4	171.0	82.11
36	99.4	126.0	78.89	94.6	105	90.10	67.1	73.0	91.9	261.1	295.0	88.51
37	116.7	128.0	91.17	87.7	100	87.70	54.3	58.0	93.6	258.7	285.0	90.77
38	198.9	278.0	71.55	82.7	91.0	90.88	83.0	97.0	85.6	364.6	415.0	87.86
39	61.2	140.0	43.71	22.9	29.0	78.97	50.7	73.0	69.5	134.8	164.2	82.10
40	133.3	151.0	88.28	35.0	37.0	94.59	71.8	77.0	93.2	240.1	277.0	86.68
41	112.1	140.0	80.07	38.9	43.0	90.47	67.2	79.0	85.1	218.2	241.0	90.54
42	114.7	164.0	69.94	34.9	41.0	85.12	55.6	69.0	80.6	205.2	240.0	85.50
43	125.5	245.0	51.22	31.3	41.0	76.34	67.1	75.0	89.5	223.9	262.0	85.46
44	160.4	188.0	85.32	41.6	44.0	94.55	85.4	92.0	92.8	287.4	324.0	88.70
45	173.5	256.0	67.77	27.0	35.0	77.14	65.5	78.0	84.0	266.0	299.0	88.96
46	138.3	160.0	86.44	32.3	38.0	85.00	58.2	79.0	73.7	228.8	266.0	86.02
47	79.5	109.0	72.94	43.6	49.0	88.98	62.5	66.0	94.7	185.6	221.0	83.98
48	179.6	241.0	74.52	38.9	41.0	94.88	91.3	174	52.5	309.8	431.0	71.88
49	104.4	117.0	89.23	14.6	21.0	69.52	62.0	74.0	83.8	181.0	211.0	85.78
50	54.3	124.0	43.79	57.9	97.0	59.69	59.1	67.0	88.2	171.3	210.0	81.57
51	78.4	86.00	91.16	38.3	45.0	85.11	89.8	138	65.1	206.5	247.0	83.60
52	122.3	139.0	87.99	43.0	46.0	93.48	58.9	64.0	92.0	224.2	271.0	82.73
53	176.5	247.0	71.46	47.1	54.0	87.22	54.6	62.0	88.1	278.2	316.0	88.04

lt1= time taken in task 1/linear menu
t1p= productive time /task 1
prt1= productivity /task 1
lt2= time taken in task 2/linear menu
t2p= productive time /task 2
prt2= productivity /task 1
lt3= time taken in task 3/linear menu
t3p= productive time /task 3
prt3= productivity /task 1
lttotal= total time taken in linear menu
lt_real= real time taken in linear menu
prl= productivity of linear menu

	ls1	ls2	ls3	lstotal	le1	le2	le3	letotal	eet1	eet2	eet3	ew
1	27	18	8	53	20	12	1	33	25.93	33.33	87.5	48.9
2	14	38	29	81	7	32	22	61	50.00	15.79	24.1	30.0
3	12	9	7	28	5	3	0	8	58.33	66.67	100	75.0
4	39	8	9	56	32	2	2	36	17.95	75.00	77.8	56.9
5	16	16	7	39	9	10	0	19	43.75	37.50	100	60.4
6	18	10	7	35	11	4	0	15	38.89	60.00	100	66.3
7	10	12	8	30	3	6	1	10	70.00	50.00	87.5	69.2
8	16	9	9	34	9	3	2	14	43.75	66.67	77.8	62.7
9	21	9	7	37	14	3	0	17	33.33	66.67	100	66.7
10	24	8	7	39	17	2	0	19	29.17	75.00	100	68.1
11	11	6	7	24	4	0	0	4	63.64	100.0	100	87.9
12	12	7	7	26	5	1	0	6	58.33	85.71	100	81.3
13	12	24	7	43	5	18	0	23	58.33	25.00	100	61.1
14	16	9	9	34	9	3	2	14	43.75	66.67	77.8	62.7
15	31	6	8	45	24	0	1	25	22.58	100.0	87.5	70.0
16	9	19	7	35	2	13	0	12	77.78	31.58	100	69.8
17	7	17	7	31	0	11	0	11	100.0	35.29	100	78.4
18	8	6	7	21	1	0	0	1	87.50	100.0	100	95.8
19	8	6	8	22	1	0	1	2	87.50	100.0	87.5	91.7
20	13	23	11	47	6	17	4	15	53.85	26.09	63.6	47.9
21	14	7	11	32	7	1	4	12	50.00	85.71	63.6	66.5
22	24	6	8	38	17	0	1	18	29.17	100.0	87.5	72.2
23	9	11	23	43	2	5	16	23	77.78	54.55	30.4	54.3
24	22	11	7	40	15	5	0	20	31.82	54.55	100	62.1
25	26	11	7	44	19	5	0	24	26.92	54.55	100	60.5
26	14	9	7	30	7	3	0	10	50.00	66.67	100	72.2
27	10	10	7	27	3	4	0	7	70.00	60.00	100	76.7
28	25	9	7	41	18	3	0	21	28.00	66.67	100	64.9
29	17	6	7	28	10	0	0	10	41.18	100.0	100	80.4
30	16	24	7	46	9	18	0	19	43.75	25.00	100	56.3
31	14	6	7	27	7	0	0	7	50.00	100.0	100	83.3
32	34	20	12	66	27	14	5	45	20.59	30.00	58.3	36.3
33	7	9	7	23	0	3	0	3	100.0	66.67	100	88.9
34	15	6	10	31	8	0	3	11	46.67	100.0	70.0	72.2
35	8	6	8	22	1	0	1	2	87.50	100.0	87.5	91.7
36	12	23	9	44	5	17	2	23	58.33	26.09	77.8	54.1
37	13	12	9	34	6	6	2	14	53.85	50.00	77.8	60.5
38	35	19	13	67	28	13	6	47	20.00	31.58	53.8	35.1
39	9	6	7	22	2	0	0	2	77.78	100.0	100	92.6
40	20	8	9	37	13	2	2	17	35.00	75.00	77.8	62.6
41	17	8	9	34	10	2	2	14	41.18	75.00	77.8	64.7
42	19	7	7	33	12	1	0	13	36.84	88.57	100	75.1
43	18	7	8	33	11	1	1	13	38.89	85.71	87.5	70.7
44	25	9	8	42	18	3	1	22	28.00	66.67	87.5	60.7
45	27	6	8	41	20	0	1	21	25.93	100.0	87.5	71.1
46	21	6	7	34	14	0	0	14	33.33	100.0	100	77.8
47	10	10	8	28	3	4	1	8	70.00	60.00	87.5	72.5
48	28	8	12	48	21	2	5	28	25.00	75.00	58.3	52.8
49	19	6	7	32	12	0	0	12	36.84	100.0	100	78.9
50	9	13	10	32	2	7	3	12	77.78	46.15	70.0	64.6
51	9	8	12	29	2	2	5	9	88.89	75.00	58.3	74.1
52	14	10	7	31	7	4	0	11	50.00	60.00	100	70.0
53	30	9	7	46	23	3	0	26	23.33	66.67	100	63.3

ls1= steps taken in task1/ linear menu
ls2= steps taken in task2/ linear menu
ls3= steps taken in task3/ linear menu
lstotal= total steps taken in linear menu
le1= error in task 1/linear menu
le2= error in task 2/linear menu
le3= error in task 3/linear menu
letotal= total error in linear menu
eet1= efficiency in task 1/ linear menu
eet2= efficiency in task 2/ linear menu
eet3= efficiency in task 3/ linear menu
ew= weighted efficiency

	nlt1	nlt2	nlt3	nlttotal	nlt_real	prnl	nls1	nls2	nls3	nlstotal	nle1	nle2	nle3	nletotal
1	50.9	45.6	40.0	136.5	158.9	85.90	4	8	8	20	0	6	3	9
2	47.3	75.0	42.3	164.6	186.6	88.21	4	10	5	19	0	8	0	8
3	53.8	41.1	41.6	136.5	211.6	64.51	4	6	5	15	0	4	0	4
4	48.4	19.5	51.5	119.4	159.0	75.09	4	2	5	11	0	0	0	0
5	41.5	31.4	53.8	126.7	168.3	75.28	4	5	6	15	0	3	1	4
6	22.1	51.6	44.1	117.8	232.6	50.64	7	8	5	20	3	6	0	9
7	48.5	19.3	27.1	94.9	147.0	64.56	4	2	5	11	0	0	0	0
8	55.5	23.3	50.2	129.0	165.5	77.95	4	3	5	12	0	1	0	1
9	67.0	22.8	45.0	134.8	172.0	78.37	4	3	5	12	0	1	0	1
10	50.1	21.9	50.9	122.9	147.0	83.61	4	2	5	11	0	0	0	0
11	37.2	58.1	33.6	128.9	156.0	82.63	4	15	5	24	0	13	0	13
12	55.1	19.6	43.5	118.2	147.0	80.41	4	4	5	13	0	2	0	2
13	43.5	48.6	123	214.6	247.0	86.88	4	8	19	31	0	6	14	20
14	63.8	23.6	47.8	135.2	167.0	80.96	4	3	5	12	0	1	0	1
15	56.9	53.6	56.8	167.3	200.0	83.65	4	12	5	21	0	10	0	10
16	47.0	29.6	58.8	135.4	169.0	80.12	4	5	5	14	0	3	0	3
17	64.6	11.0	54.3	129.9	165.0	78.73	4	2	5	11	0	0	0	0
18	115	30.9	64.6	210.9	237.0	88.99	15	6	7	28	11	4	2	17
19	54.9	10.6	33.4	98.9	110.0	89.91	4	2	5	11	0	0	0	0
20	47.2	11.0	32.3	90.5	113.0	80.09	4	2	5	11	0	0	0	0
21	43.1	14.6	50.2	107.9	134.0	80.52	4	3	5	12	0	1	0	1
22	50.6	16.6	46.7	113.9	140.0	81.36	4	2	8	14	0	0	3	3
23	66.8	10.0	81.2	158.0	191.0	82.72	4	2	8	14	0	0	3	3
24	67.0	22.8	49.7	139.5	162.0	86.11	4	5	5	14	0	3	0	3
25	55.9	51.4	39.3	146.6	172.0	85.23	6	10	5	21	2	8	0	10
26	42.1	18.9	33.7	94.7	122.0	77.62	4	5	5	14	0	3	0	3
27	48.9	11.0	54.5	114.4	151.0	75.76	4	2	6	12	0	0	1	1
28	59.7	10.1	60.1	129.9	165.0	78.73	7	2	8	17	3	0	3	6
29	49.5	10.6	53.0	113.1	150.0	75.40	4	2	5	11	0	0	0	0
30	53.7	38.3	50.5	142.5	177.0	80.51	4	9	5	18	0	7	0	7
31	56.2	6.3	53.9	116.4	144.0	80.83	4	2	6	12	0	0	1	1
32	61.1	25.9	47.0	134.0	165.0	81.21	6	5	5	16	2	3	0	5
33	178	6.9	38.4	222.9	255.0	87.41	30	2	5	37	26	0	0	26
34	61.7	7.0	50.7	119.4	147.0	81.22	5	4	6	15	1	2	1	4
35	54.9	10.6	10.0	75.5	100.0	75.50	4	2	5	11	0	0	0	0
36	51.2	11.0	44.4	106.6	136.0	78.38	4	2	5	11	0	0	0	0
37	41.0	14.0	38.9	93.9	107.0	87.76	4	2	5	11	0	0	0	0
38	53.1	26.9	47.0	127.0	155.8	81.51	7	6	5	18	3	4	0	7
39	41.0	11.6	54.6	107.2	136.0	78.82	4	2	7	13	0	0	2	2
40	48.3	10.3	62.5	121.1	155.0	78.13	4	2	5	11	0	0	0	0
41	64.0	15.0	55.0	134.0	167.0	80.24	4	3	6	13	0	1	1	2
42	59.5	14.6	50.8	124.9	163.0	76.63	4	3	5	12	0	1	0	1
43	75.1	23.0	62.8	160.9	199.0	80.85	5	4	7	16	1	2	2	5
44	69.8	22.9	59.1	151.8	186.0	81.61	4	4	6	14	0	2	1	3
45	59.4	26.6	62.9	148.9	181.0	82.27	4	6	5	15	0	4	0	4
46	55.1	11.0	27.4	93.5	128.0	73.05	4	2	5	11	0	0	0	0
47	54.4	10.6	54.9	119.9	152.0	78.88	4	2	5	11	0	0	0	0
48	47.3	10.6	58.2	116.1	156.0	74.42	4	2	7	13	0	0	2	2
49	40.4	24.9	37.6	102.9	132.0	77.95	4	7	5	16	0	0	0	0
50	58.9	18.9	36.9	114.7	216.0	53.10	4	4	5	13	0	2	0	2
51	61.5	68.7	45.9	176.1	216.0	81.53	5	13	5	23	1	0	0	1
52	54.3	6.3	50.3	110.9	149.0	74.43	4	2	5	11	0	0	0	0
53	50.3	20.9	57.7	128.9	170.0	75.82	4	5	5	14	0	3	0	3

nlt1= time taken in task 1/non-linear menu
nlt2= time taken in task 2/non-linear menu
nlt3= time taken in task 3/non-linear menu
nlttotal=total time taken in non-linear menu
nlt_real=real time taken in non-linear menu
prnl= productivity of non-linear menu
nls1= steps taken in task1/ non-linear menu
nls2= steps taken in task2/ non-linear menu
nls3= steps taken in task3/ non-linear menu
nlstotal=total steps taken in non-linear menu
nle1= error made in task1 /non-linear menu
nle2= error made in task 2/ non-linear menu
nle3= error made in task 3/ non-linear menu
nletotal= total error made in non-linear menu

Satisfaction score Statistics

Report

Profession	Sex		Satisfaction score of Linear Menu	Satisfaction score of Non-Linear menu	Score of Task1in Linear menu	Score of Task1 in Non-Linear menu
Student	Female	Mean	106.57	129.14	19.50	26.21
		N	14	14	14	14
		Std. Deviation	16.887	9.404	4.637	5.618
	Male	Mean	117.00	126.08	21.33	26.67
		N	12	12	12	12
		Std. Deviation	12.128	15.577	3.172	4.924
	Total	Mean	111.38	127.73	20.35	26.42
		N	26	26	26	26
		Std. Deviation	15.528	12.457	4.059	5.209
Technician	Female	Mean	100.20	124.00	18.20	27.60
		N	5	5	5	5
		Std. Deviation	23.350	8.888	4.550	1.817
	Male	Mean	103.14	125.41	19.86	27.86
		N	22	22	22	22
		Std. Deviation	20.136	20.231	5.045	4.086
	Total	Mean	102.59	125.15	19.56	27.81
		N	27	27	27	27
		Std. Deviation	20.315	18.522	4.917	3.742
Total	Female	Mean	104.89	127.79	19.16	26.58
		N	19	19	19	19
		Std. Deviation	18.315	9.319	4.525	4.891
	Male	Mean	108.03	125.65	20.38	27.44
		N	34	34	34	34
		Std. Deviation	18.769	18.478	4.479	4.364
	Total	Mean	106.91	126.42	19.94	27.13
		N	53	53	53	53
		Std. Deviation	18.492	15.742	4.491	4.532

Report

Profession	Sex		Score of Task2 in Linear menu	Score of Task2 in Non-Linear menu	Score of Task3 in Linear menu	Score of Task3 in Non-Linear menu
Student	Female	Mean	23.36	27.21	26.00	26.50
		N	14	14	14	14
		Std. Deviation	5.486	2.424	4.403	4.292
	Male	Mean	25.08	27.92	26.83	27.00
		N	12	12	12	12
		Std. Deviation	6.037	3.029	2.480	3.742
	Total	Mean	24.15	27.54	26.38	26.73
		N	26	26	26	26
		Std. Deviation	5.697	2.687	3.601	3.976
Technician	Female	Mean	21.20	24.60	23.60	26.60
		N	5	5	5	5
		Std. Deviation	8.643	5.320	2.966	4.930
	Male	Mean	22.23	25.82	23.32	26.64
		N	22	22	22	22
		Std. Deviation	5.468	6.261	4.633	4.933
	Total	Mean	22.04	25.59	23.37	26.63
		N	27	27	27	27
		Std. Deviation	5.984	6.021	4.325	4.837
Total	Female	Mean	22.79	26.53	25.37	26.53
		N	19	19	19	19
		Std. Deviation	6.268	3.454	4.139	4.325
	Male	Mean	23.24	26.56	24.56	26.76
		N	34	34	34	34
		Std. Deviation	5.753	5.389	4.315	4.493
	Total	Mean	23.08	26.55	24.85	26.68
		N	53	53	53	53
		Std. Deviation	5.886	4.750	4.231	4.393

ANOVA: Profession vs. Satisfaction Score

		Sum of Squares	df	Mean Square	F	Sig.
Satisfaction score of Linear Menu	Between Groups	1023.856	1	1023.856	3.116	.084
	Within Groups	16758.672	51	328.601		
	Total	17782.528	52			
Satisfaction score of Non-Linear menu	Between Groups	88.345	1	88.345	.352	.556
	Within Groups	12798.523	51	250.951		
	Total	12886.868	52			

ANOVA: Gender vs. Satisfaction score

		Sum of Squares	df	Mean Square	F	Sig.
Satisfaction score of Linear Menu	Between Groups	119.768	1	119.768	.346	.559
	Within Groups	17662.760	51	346.329		
	Total	17782.528	52			
Satisfaction score of Non-Linear menu	Between Groups	55.945	1	55.945	.222	.639
	Within Groups	12830.923	51	251.587		
	Total	12886.868	52			

ANOVA :Age vs. satisfaction score

		Sum of Squares	df	Mean Square	F	Sig.
Satisfaction score of Linear Menu	Between Groups	799.703	4	199.926	.565	.689
	Within Groups	16982.825	48	353.809		
	Total	17782.528	52			
Satisfaction score of Non-Linear menu	Between Groups	536.513	4	134.128	.521	.720
	Within Groups	12350.355	48	257.299		
	Total	12886.868	52			

Error Statistics

Report

Profession	Sex		Error made in linear menu	Error made in non-linear menu	Error made in completing task1 in linear menu	Error made in completing task1 in non-linear menu
Student	Female	Mean	13.29	4.64	7.07	2.21
		N	14	14	14	14
		Std. Deviation	11.730	8.120	7.259	6.908
	Male	Mean	14.83	5.00	10.17	1.00
		N	12	12	12	12
		Std. Deviation	9.562	5.641	9.989	3.162
	Total	Mean	14.00	4.81	8.50	1.65
		N	26	26	26	26
		Std. Deviation	10.602	6.951	8.590	5.440
Technician	Female	Mean	19.40	4.60	13.60	.40
		N	5	5	5	5
		Std. Deviation	9.581	4.615	7.335	.894
	Male	Mean	19.18	2.68	11.55	.36
		N	22	22	22	22
		Std. Deviation	12.868	2.589	7.110	.902
	Total	Mean	19.22	3.04	11.93	.37
		N	27	27	27	27
		Std. Deviation	12.160	3.044	7.054	.884
Total	Female	Mean	14.89	4.63	8.79	1.74
		N	19	19	19	19
		Std. Deviation	11.289	7.236	7.664	5.943
	Male	Mean	17.65	3.50	11.06	.59
		N	34	34	34	34
		Std. Deviation	11.845	4.017	8.116	1.987
	Total	Mean	16.66	3.91	10.25	1.00
		N	53	53	53	53
		Std. Deviation	11.616	5.354	7.959	3.878

Report

Profession	Sex		Error made in completing task2 in linear menu	Error made in completing task2 in non-linear menu	Error made in completing task3 in linear menu	Error made in completing task3 in non-linear menu
Student	Female	Mean	6.14	1.07	1.07	1.36
		N	14	14	14	14
		Std. Deviation	7.070	1.940	1.639	3.734
	Male	Mean	5.00	3.75	.58	.25
		N	12	12	12	12
		Std. Deviation	5.970	4.224	.996	.622
	Total	Mean	5.62	2.31	.85	.85
		N	26	26	26	26
		Std. Deviation	6.481	3.415	1.377	2.781
Technician	Female	Mean	4.80	3.00	1.00	1.20
		N	5	5	5	5
		Std. Deviation	4.438	3.742	.707	1.643
	Male	Mean	4.45	1.77	3.18	.55
		N	22	22	22	22
		Std. Deviation	6.965	2.159	5.535	.912
	Total	Mean	4.51	2.00	2.78	.67
		N	27	27	27	27
		Std. Deviation	6.499	2.481	5.056	1.074
Total	Female	Mean	5.79	1.58	1.05	1.32
		N	19	19	19	19
		Std. Deviation	6.391	2.567	1.433	3.267
	Male	Mean	4.64	2.47	2.26	.44
		N	34	34	34	34
		Std. Deviation	6.544	3.136	4.627	.824
	Total	Mean	5.05	2.15	1.83	.75
		N	53	53	53	53
		Std. Deviation	6.452	2.951	3.827	2.075

ANOVA: Profession vs. Error

		Sum of Squares	df	Mean Square	F	Sig.
Error made in linear menu	Between Groups	361.220	1	361.220	2.768	.102
	Within Groups	6654.667	51	130.484		
	Total	7015.887	52			
Error made in non-linear menu	Between Groups	41.527	1	41.527	1.462	.232
	Within Groups	1449.001	51	28.412		
	Total	1490.528	52			

ANOVA: Gender vs. profession

		Sum of Squares	df	Mean Square	F	Sig.
Error made in linear menu	Between Groups	92.333	1	92.333	.680	.413
	Within Groups	6923.554	51	135.756		
	Total	7015.887	52			
Error made in non-linear menu	Between Groups	15.607	1	15.607	.540	.466
	Within Groups	1474.921	51	28.920		
	Total	1490.528	52			

ANOVA: Error vs. age

		Sum of Squares	df	Mean Square	F	Sig.
Error made in linear menu	Between Groups	969.963	4	242.491	1.925	.121
	Within Groups	6045.923	48	125.957		
	Total	7015.887	52			
Error made in non-linear menu	Between Groups	79.699	4	19.925	.678	.611
	Within Groups	1410.830	48	29.392		
	Total	1490.528	52			

Time Statistics

Report

Profession	Sex		Time taken in linear menu	Time taken in non-linear menu	Time taken to complete task1 in linear menu	Time taken to complete task1 in non-linear menu
Student	Female	Mean	220.436	126.100	162.8571	61.043
		N	14	14	14	14
		Std. Deviation	64.1405	42.8185	70.42711	34.0280
	Male	Mean	249.408	133.808	173.7500	57.717
		N	12	12	12	12
		Std. Deviation	61.9224	31.3226	73.18361	20.2328
	Total	Mean	233.808	129.658	167.8846	59.508
		N	26	26	26	26
		Std. Deviation	63.5875	37.4223	70.47288	28.0194
Technician	Female	Mean	239.560	129.180	234.4000	53.460
		N	5	5	5	5
		Std. Deviation	41.9164	13.0064	91.99348	2.5363
	Male	Mean	245.977	130.177	169.3182	54.073
		N	22	22	22	22
		Std. Deviation	78.6050	21.9319	55.86752	12.2435
	Total	Mean	244.789	129.993	181.3704	53.959
		N	27	27	27	27
		Std. Deviation	72.5761	20.3639	66.98229	11.0510
Total	Female	Mean	225.468	126.911	181.6842	59.047
		N	19	19	19	19
		Std. Deviation	58.6219	36.9280	80.68736	29.1455
	Male	Mean	247.188	131.459	170.8824	55.359
		N	34	34	34	34
		Std. Deviation	72.2000	25.2237	61.45004	15.3288
	Total	Mean	239.402	129.828	174.7547	56.681
		N	53	53	53	53
		Std. Deviation	67.8844	29.6758	68.39110	21.1270

Report

Profession	Sex		Time taken to complete task2 in linear menu	Time taken to complete task2 in non-linear menu	Time taken to complete task3 in non-linear menu	Time taken to complete task3 in non-linear menu
Student	Female	Mean	64.2857	16.950	74.7857	48.107
		N	14	14	14	14
		Std. Deviation	31.73551	12.9178	18.75829	24.7330
	Male	Mean	61.4167	27.575	73.0833	48.517
		N	12	12	12	12
		Std. Deviation	31.43958	15.6707	12.42767	11.2487
	Total	Mean	62.9615	21.854	74.0000	48.296
		N	26	26	26	26
		Std. Deviation	30.99610	14.9666	15.86443	19.3342
Technician	Female	Mean	99.8000	29.500	91.6000	46.220
		N	5	5	5	5
		Std. Deviation	63.44052	18.0339	26.67021	6.6706
	Male	Mean	59.0909	24.600	91.3636	51.505
		N	22	22	22	22
		Std. Deviation	47.67440	18.1529	34.69808	11.2689
	Total	Mean	66.6296	25.507	91.4074	50.526
		N	27	27	27	27
		Std. Deviation	52.10208	17.8873	32.89173	10.6672
Total	Female	Mean	73.6316	20.253	79.2105	47.611
		N	19	19	19	19
		Std. Deviation	43.35796	15.0008	21.68097	21.2700
	Male	Mean	59.9118	25.650	84.9118	50.450
		N	34	34	34	34
		Std. Deviation	42.15582	17.1359	29.93768	11.1843
	Total	Mean	64.8302	23.715	82.8679	49.432
		N	53	53	53	53
		Std. Deviation	42.69243	16.4642	27.18670	15.4233

ANOVA: Time vs. profession

		Sum of Squares	df	Mean Square	F	Sig.
Time taken in linear menu	Between Groups	1597.205	1	1597.205	.342	.561
	Within Groups	238033.725	51	4667.328		
	Total	239630.930	52			
Time taken in non-linear menu	Between Groups	1.486	1	1.486	.002	.968
	Within Groups	45792.562	51	897.893		
	Total	45794.048	52			

ANOVA: Time vs. gender

		Sum of Squares	df	Mean Square	F	Sig.
Time taken in linear menu	Between Groups	5750.013	1	5750.013	1.254	.268
	Within Groups	233880.916	51	4585.900		
	Total	239630.930	52			
Time taken in non-linear menu	Between Groups	252.147	1	252.147	.282	.597
	Within Groups	45541.900	51	892.978		
	Total	45794.048	52			

ANOVA: time vs. age

		Sum of Squares	df	Mean Square	F	Sig.
Time taken in linear menu	Between Groups	27366.692	4	6841.673	1.547	.204
	Within Groups	212264.237	48	4422.172		
	Total	239630.930	52			
Time taken in non-linear menu	Between Groups	472.231	4	118.058	.125	.973
	Within Groups	45321.816	48	944.205		
	Total	45794.048	52			

Productivity and efficiency

Report

Profession	Sex		Efficiency at d=3	Efficiency at d=4	Productivity at d=3	Productivity at d=4
Student	Female	Mean	64.4920	58.9850	83.3344	68.3455
		N	14	14	14	14
		Std. Deviation	29.66123	22.04286	15.23046	18.32391
	Male	Mean	67.7571	53.4038	89.6334	76.4556
		N	12	12	12	12
		Std. Deviation	28.51676	26.48956	7.49762	9.02429
	Total	Mean	65.9990	56.4091	86.2417	72.0886
		N	26	26	26	26
		Std. Deviation	28.60168	23.86335	12.47446	15.08081
Technician	Female	Mean	62.9091	39.1531	65.0141	56.9289
		N	5	5	5	5
		Std. Deviation	24.20224	18.68772	30.16344	13.90484
	Male	Mean	69.6470	44.3767	84.8478	72.3452
		N	22	22	22	22
		Std. Deviation	22.94836	19.47020	9.24775	15.91712
	Total	Mean	68.3993	43.4093	81.1749	69.4903
		N	27	27	27	27
		Std. Deviation	22.86005	19.08377	16.45263	16.48086
Total	Female	Mean	64.0755	53.7661	78.5133	65.3411
		N	19	19	19	19
		Std. Deviation	27.67819	22.56162	20.93834	17.66750
	Male	Mean	68.9800	47.5627	86.5368	73.7959
		N	34	34	34	34
		Std. Deviation	24.63809	22.23310	8.86280	13.86892
	Total	Mean	67.2218	49.7866	83.6605	70.7649
		N	53	53	53	53
		Std. Deviation	25.61356	22.33649	14.72063	15.71212

Comperative summary

Variables	Profession	Statistics		
		Minimum	Maximum	Mean
Total steps taken to complete tasks in linear menu	Student	21	66	34.85
	Technician	22	81	39.22
	Total	21	81	37.08
Steps taken in non-linear menu	Student	11	37	15.81
	Technician	11	23	14.63
	Total	11	37	15.21
Time taken in linear menu	Student	140.4	362.1	233.808
	Technician	134.8	511.4	244.789
	Total	134.8	511.4	239.402
Time taken in non-linear menu	Student	75.5	222.9	129.658
	Technician	93.5	176.1	129.993
	Total	75.5	222.9	129.828
Error made in linear menu	Student	1	45	14.00
	Technician	2	61	19.22
	Total	1	61	16.66
Error made in non-linear menu	Student	0	26	4.81
	Technician	0	10	3.04
	Total	0	26	3.91
Error made in linear menu - Error made in non-linear menu	Student	1	19	9.19
	Technician	2	51	16.19
	Total	1	35	12.75
Error made in linear menu - Error made in non-linear menu) / Error made in non-linear menu * 100%	Student	.	73.1%	191.2%
	Technician	.	510.0%	532.9%
	Total	.	134.6%	326.6%
Total steps taken to complete tasks in linear menu - Steps taken in non-linear menu	Student	10	29	19.04
	Technician	11	58	24.59
	Total	10	44	21.87
Total steps taken to complete tasks in linear menu - Steps taken in non-linear menu) / Steps taken in non-linear menu * 100%	Student	90.9%	78.4%	120.4%
	Technician	100.0%	252.2%	168.1%
	Total	90.9%	118.9%	143.8%
Time taken in linear menu - Time taken in non-linear menu	Student	64.9	139.2	104.150
	Technician	41.3	335.3	114.796
	Total	59.3	288.5	109.574
Time taken in linear menu - Time taken in non-linear menu) / Time taken in non-linear menu * 100%	Student	86.0%	62.4%	80.3%
	Technician	44.2%	190.4%	88.3%
	Total	78.5%	129.4%	84.4%

Case Summaries

								Subject
Age	>20	Sex	Male	Profession	Technician	1		S50
						2		S51
						3		S52
						4		S53
						Total	N	**4**
					Total	N		**4**
			Total	N				**4**
	21-35	Sex	Female	Profession	Student	1		S3
						2		S12
						3		S13
						4		S19
						5		S20
						6		S27
						7		S28
						8		S29
						9		S31
						10		S33
						11		S34
						12		S32
						13		S36
						14		S37
						Total	N	**14**
					Technician	1		S1
						2		S8
						3		S22
						4		S25
						5		S47
						Total	N	**5**
					Total	N		**19**
			Male	Profession	Student	1		S10
						2		S11
						3		S15
						4		S16
						5		S17
						6		S18
						7		S24
						8		S26
						9		S30
						10		S35
						Total	N	**10**
					1 Technician	1		S2
						2		S9
						3		S21
						4		S23
						5		S49
						Total	N	**5**
					Total	N		**15**
			Total	N				**34**
	36-50	Sex	Male	Profession	Student	1		S7
						Total	N	**1**
					Technician	1		S5
						2		S6
						3		S14
						4		S39
						5		S40
						6		S42
						7		S43
						8		S44
						9		S45
						10		S46
						Total	N	**10**
					Total	N		**11**
			Total	N				**11**
	51-65	Sex	Male	Profession	Technician	1		S38
						2		S41
						3		S48
						Total	N	**3**
					Total	N		**3**
			Total	N				**3**
	<65	Sex	Male	Profession	Student	1		S4
						Total	N	**1**
					Total	N		**1**
			Total	N				**1**
	Total	N						**53**

k

Appendix B

Questionnaire

Einverständniserklärung

Hiermit erkläre ich mich damit einverstanden, daß der PDA Menüfuhrungs-Test, an dem ich teilnehme, auf dem Rechner aufgezeichnet wird.

Diese Daten dürfen für wissenschaftliche Zwecke genutzt werden.

Datum **Unterschrift**

Einführung

Herzlich Willkommen zum PDA Menüführungs-Test

Darum geht es:

Um die Bedienbarkeit von PDA (Personal Digital Assistants) weiter zu erforschen, werden sogenannte „Benutzerführung-Tests " durchgeführt.

Dabei werden von „repräsentativen " Benutzern - wie Sie es sind - typische Aufgaben mit PDA Simulation durchgeführt. Dies wird automatisch auf dem Rechner, während Sie ihn bedienen, aufgezeichnet.

Ziel dabei ist es, Schwachstellen und ein Vergleich zwischen linearen Menüs (üblichen) und nicht linearen Menüs in der Bedienbarkeit des PDAs festzustellen.

Wenn Sie also Schwierigkeiten bei der Lösung der Aufgaben haben, zweifeln Sie nicht an Ihren technischen Fähigkeiten.

Ganz wichtig dabei: Nicht Sie werden getestet, sondern das Produkt!

Ihr Feedback gibt dem Bearbeiter wichtige Anstöße für weitere Verbesserungen neuer Menüführung - Generationen.

Stellen Sie sich vor ein Handwerksbetriebsleiter zu sein. Ihr Betrieb bekommt verschiedene, übliche Aufträge vom Kunden, z.B. eine Wasserhahn-Reparatur.

Aufgabe 1

Erfassen Sie einen neuen Auftrag auf der PDA Benutzeroberfläche, wobei Sie Folgendes angeben:
Datum: 17.12.2005
Auftrags Nr.: HW 121
Kunden Name: Michael Möller
Strasse: Harrisleer Str.
Haus- Nr.: 78
PLZ: 24939
Ort: Flensburg
Einsatzort: Jardelund
Einsatzzeit: 14 Uhr
Auftragsart: Reparatur
Dauer: 2 std.

Fragebogen 1

1= trifft zu ....**5**= trifft nicht zu

	1	2	3	4	5
Es war einfach mit dem PDA einen neuen Auftrag zu erfassen	☐	☐	☐	☐	☐
Es war einfach mit der Aufgabe anzufangen	☐	☐	☐	☐	☐
Das Menü war verständlich und hat geholfen um die Aufgabe auszuführen?	☐	☐	☐	☐	☐
Ich wusste Bescheid über den nächsten Schritt im dargestellten Menü, nachdem ich den ersten Schritt gemacht hatte	☐	☐	☐	☐	☐
Es war einfach, auf einen vorhergehenden Schritt im Menü zurückzugehen	☐	☐	☐	☐	☐
Es gab Momente in denen ich nicht wusste, was als nächste zu tun war	☐	☐	☐	☐	☐

Aufgabe 2

Nun haben Sie festgestellt, dass das Datum in der letzten Aufgabe nicht stimmt. Bitte ändern Sie es. **Das neue Datum soll sein: 27.11.2005**

Fragebogen 2

1= trifft zu ....**5**= trifft nicht zu

	1	2	3	4	5
Es war einfach Datum zu ändern	☐	☐	☐	☐	☐
Es war einfach mit der Aufgabe anzufangen	☐	☐	☐	☐	☐
Das Menü war verständlich und hat geholfen um die Aufgabe auszuführen?	☐	☐	☐	☐	☐
Ich wusste Bescheid über den nächsten Schritt im dargestellten Menü, nachdem ich den ersten Schritt gemacht hatte	☐	☐	☐	☐	☐
Es war einfach, auf einen vorhergehenden Schritt im Menü zurückzugehen	☐	☐	☐	☐	☐
Es gab Momente in denen ich nicht wusste was als nächstes zu tun war	☐	☐	☐	☐	☐

Aufgabe 3:

Als Betriebsleiter wollen Sie eine Datenbank anlegen. Diese Datenbank beinhaltet eine Mitarbeiter-Datenbank, eine Geräte-Datenbank, eine Material-Datenbank und eine Kunden-Datenbank.
Bitte legen Sie eine neue Mitarbeiter-Datenbank an, wobei Sie Folgendes angeben:
Datenbank Name: MADB13
Max. Datensätze: 50
Mitarbeiter Name: Ja
Anschrift: Nein
PLZ: Ja
Ort: Ja
Telefon: Nein
Notiz: Ja

Fragebogen 3

1= trifft zu ....**5**= trifft nicht zu

	1	2	3	4	5
Es war einfach mit dem PDA einen neuen Datenbank zu zulegen	☐	☐	☐	☐	☐
Es war einfach mit der Aufgabe anzufangen	☐	☐	☐	☐	☐
Das Menü war verständlich und hat geholfen um die Aufgabe auszuführen	☐	☐	☐	☐	☐
Ich wusste Bescheid über den nächsten Schritt im dargestellten Menü, nachdem ich den ersten Schritt gemacht hatte	☐	☐	☐	☐	☐
Es war einfach, auf einen vorhergehenden Schritt im Menü zurückzugehen	☐	☐	☐	☐	☐
Es gab Momente in denen ich nicht wusste was als nächstes zu tun war	☐	☐	☐	☐	☐

Abschlussfragebogen

1= trifft zu ....**5**= trifft nicht zu

	1	2	3	4	5
Es war einfach, das Menü des PDA zu bedienen	☐	☐	☐	☐	☐
Die Anordnung des Menüs auf der PDA Oberfläche war angemessen	☐	☐	☐	☐	☐
Die Art und Weise, mit der man das Menü des PDA bedienen konnte, war verständlich	☐	☐	☐	☐	☐
Die graphischen Darstellungen auf dem Display waren verständlich	☐	☐	☐	☐	☐
Diese Art von Menü erfüllt meine Ansprüchen	☐	☐	☐	☐	☐

Ich bedanke mich ganz herzlich für Ihren Einsatz und Ihre Bemühungen.

Auf Wiedersehen.

Appendix C

Test example: linear menu (task1)


Start
3:11
Auftrag
Datenbank
Info
Neu
Verwalten
Öffnen
Erfassen
Speichern
Zurück
Bearbeiten
Drücken
Beenden
New
iPAQ
Start
3:11
Auftrag
Datenbank
Info
Neu
Verwalten
Öffnen
Erfassen
Speichern
Zurück
Bearbeiten
Drucken
Beenden
Auftrags Nr.
Datum
New
iPAQ

r


Start
3:11
Auftrag
Datenbank
Info
Datum
17.12.2005
Auftrags Nr.
HW 121
Weiter
New
iPAQ
Start
3:11
Auftrag
Datenbank
Info
Kunde
Michael Möller
Strasse
Haus-Nr.
PLZ
Ort
Einsatzort
Einsatzzeit
Auftragsart
Dauer
New
iPAQ


Start
3:11
|Auftrag| |Datenbank| |Info|
PHOTOSMART
MOBILE
MEDIA
PHOTOS
HOME
CONTROL
hp
New
iPAQ


Start
3:11
|Auftrag| |Datenbank| |Info|
INFO
Auftrag wurde erfolgreich
Erfasst!
New
iPAQ

t

Test example: non- linear menu (task1)


Start
3:11
Auftrag erfassen
Datum
17.12.2005
Auftrags Nr.
HW 121
Drucken
Beenden
Auftrag
Öffnen
Internet
Hauptmenü
New
iPAQ


Start
3:11
Auftrag erfassen
Kundenname
Michael
Strasse
Haus-Nr.
PLZ
Ort
Einsatzort
Einsatzzeit
Auftragsart
Dauer
Neu
Öffnen
Beenden
Auftrag
Speichern
Bearbeiten
Hauptmenü
New
iPAQ

Start
3:11
Auftrag erfassen
Kundenname
Michael Möller
Strasse
Harrisleer Str.
Haus-Nr.
78
PLZ
24939
Ort
Flensburg
Einsatzort
Jardelund
Einsatzzeit
14Uhr
Auftragsart
Reparatur
Dauer
2 std.
Neu
Öffnen
Beenden
Auftrag
Speichern
Bearbeiten
Hauptmenü
New
iPAQ

Start
3:11
Bestätigung
Erfassen
Öffnen
Beenden
Auftrag
Bearbeiten
Internet
Hauptmenü
New
iPAQ

W

VITA

Sanjay Kumar Tripathi was born on July 01, 1971 in Allahabad, Uttar-Pradesh, India. He attended high school at Colonelganj Intermediate College in Allahabad, Uttar-Pradesh, where he grew up. He received his Bachelor of Technology degree in Agricultural Engineering at University of Allahabad, Uttar-Pradesh in 1994. He received his Masters of Science degree in Appropriate Rural Technology and Extension Skills (ARTES) at the International Institute of Management, University of Flensburg, Germany in 1999.
After his graduate work, Sanjay has served as a project member in the Flensburg University of Applied Science, working on a project related to ergonomics and usability of 3G mobile phones. He has also worked as a consultant for a number of organisations in both India and Germany.