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HUMAN-CENTRED DESIGN FOR DIGITAL SERVICES

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Keywords

Abstract

Human–Computer Interaction (HCI) is a multidisciplinary field concerned with the design, evaluation and use of interactive computer systems that are effective, efficient, accessible and satisfying for diverse users. This study examines the principles, theoretical foundations and practical techniques of HCI, with particular emphasis on user-centred design and usability in web-based and mobile digital services. The study traces the evolution of computing interfaces from machine-centred systems to contemporary human-centred approaches involving graphical interfaces, touch interaction, voice interfaces, mobile computing and artificial intelligence.

The research focuses on the interaction between humans, computers and their surrounding physical, social and cultural contexts. It examines important HCI concepts including human perception and cognition, mental models, interaction techniques, feedback, affordances, constraints, mapping, usability and accessibility. Particular attention is given to the Indian digital environment, where users may differ considerably in language, education, digital experience, device capability and connectivity. These factors can significantly influence the accessibility and usability of essential digital services.

The study aims to identify common usability problems, evaluate user performance and experience, assess accessibility, and examine the effectiveness of user-centred design and usability evaluation techniques. The research employs heuristic evaluation, structured surveys, task-based usability testing, and accessibility auditing. A redesigned high-fidelity prototype is evaluated against an existing baseline system using measures

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	such as task completion rate, task completion time, error frequency and perceived usability. The study is expected to contribute an integrated framework of HCI principles and practical design recommendations for developing effective, accessible and user-friendly interactive systems. The findings are particularly relevant to public digital services, where improved usability and inclusive design can reduce interaction failures and help ensure equitable access for diverse user groups.

Introduction

Human – Computer Interaction (HCI) is a field of study that has a multidisciplinary nature and is concerned with the design, evaluation and use of user computer systems that are easy and efficient to use by human and with the study of the major phenomena of these systems. Indeed, although the term itself did not become widespread in the academic parlance until the early 1980s the problems it addresses have existed since the dawn of computing: how an individual acquires an intention to act; how she communicates it to the computer; how she interprets the computer's reply and how her intention changes in the light of that reply. All keyboards, all menus, all gestures and all verbal instructions are attempts to make the human want closer to the machine that can be told.

This distance has shrunk significantly over the last 70 years, but has not and never will close. With each generation of computing technology, there are new avenues for communicative interaction, and new misunderstandings as well. The punched card was replaced by the teletype, then by the command line, then by the graphical user interface, then by direct manipulation on touch surfaces, then by speech, gesture and increasingly by systems that make inferences about the intent, rather than waiting for instructions. Each transition had the Tech world making some wrong assumptions about the users. What worked on the whiteboard didn't work out in the field. There were some interfaces created to make their creators happy, that made everyone else "huh? The message of the discipline is that it's impossible to get the latter (interactional quality) from the former (computational power).

That is the edict which is the beginning point of the present study. It is about the principles, techniques and evaluation methods in designing an interactive system that is not based on the ease of implementation but on the capabilities and limitations of the human. It tackles this issue both theoretically – by systematically reviewing the theoretical background of HCI – and empirically – by studying the usability of a particular class of interactive system, namely a public service portal that is served concurrently by web and mobile channels. The idea is to alternate between theory and practice: to write literature that reflects what is good interaction design; to subject those claims to probing by observing real people doing real things; and to develop a set of design principles that can be used by working designers.

1.2 Background of the Study

1.2.1 The Evolution of Computing and Interaction

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The first generation of electronic computers lacked any recognisable interaction. The first stored-programme computers of the late nineteen-forties were batch machines, in which the instructions were prepared in advance, submitted to the machine and waited for hours and even days for processing. The operator was not a user served by the machine, but was a technician serving the machine. If any, interaction was limited to the setting of switches and the reading of indicator lamps. The concept of making a computer easy to use by a non-specialist would have been regarded as crazy, for there weren't any non-specialists.

It was a few insightful works that led to the conceptual change. Bush (1945) postulated a concept of a machine he called the memex on which one could record books, records and communications, and retrieve them by associative paths, similar to the way the human mind works. The machine was never constructed, but the essay did lay down a lasting one: the value of a machine is its ability to amplified human intellectual labor, not just its ability to compute. Licklider (1960) expounded the argument in his account of man–computer symbiosis, wherein men would be the ones to establish goals and to frame hypotheses, and machines would do the tedium that would lay the foundation for insight. Engelbart (1963) expressed the same vision as augmentation of human intellect, and delivered a legendary public presentation in 1968 that unveiled the mouse, hypertext linking and screen windowing and collaborative editing all in one go.

In 1963, Sutherland proposed the first true graphical interactive system in Sketchpad, where the user could use a light pen to draw on a screen and the system, through the drawing of a box, made it possible to set up geometric constraints that were maintained automatically. The sketchpad was first invented twenty years prior to its availability in the marketplace, as a valid paradigm of interactions through direct graphical manipulation. These threads were synthesized by the desktop metaphor, the overlapping window, the icon, the pull-down menu and the pointing device, a series of Xerox Palo Alto Research Centre developments, which were commercialized by systems of the nineteen-eighties and then became ubiquitous.

Two later developments of the nineties are worth noting not only because of their significance for HCI but also because of the fact that they represent the rise of HCI as a self-aware discipline as well as a set of engineering practices. The first was the publication of Card, Moran and Newell's account of the human information processor and the keystroke-level model of interactive performance, which showed that some characteristics of interactive performance could be predicted quantitatively from the breakdown of tasks into simple operations. This made clear that interface design was not just a matter of taste, but could also be an engineering science with a predictive theory. The second was Shneiderman's statement of direct manipulation as a design philosophy with three key characteristics: continuous representation of objects of interest, physical action instead of complex syntax, and rapid incremental reversible operations, where the impact of the operation on the object of interest is immediately apparent. Direct manipulation provides the conceptual basis for the empirical success of the graphical interface, and served as a yardstick in evaluating subsequent paradigms.

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The next path is a well-trodden one. The personal computer turned computing into a home affair. With the coming of the World Wide Web, information retrieval became a daily skill and gave rise to a large user base of untrained users who would not tolerate being hindered. Mobile telephony enabled computing to be carried on continuously and whilst on the move, thus making interaction part of everyday life. The middle man pointing device was eliminated by touchscreens. For some classes of task the visual display was eliminated by voice interfaces. Distributed computation in the physical world with ubiquitous sensing, wearables and networked appliances. More recently, systems with machine learning have started to become proactive, based on an inferred intention, rather than only reactive, and issues of control, predictability and trust are still being resolved.

1.2.2 From Machine-Centred to Human-Centred Computing

This technical sequence is from a slower change of orientation. With regard to interface design, the initial system designs were machine-centred - that is, the interface was designed based upon the capability of the hardware and the user became accustomed to it. This is because the number of users was small, the users were technically-skilled, and professionally motivated. With the advent of the computer and its widespread usage by the general public this was no longer possible. Unless you teach the modern user how to use your service, he or she will not read the instructions, definitely not persevere if there is something easier to click on and will definitely leave if he or she doesn't grasp your service in a couple seconds.

This has led to the adaptation burden having been turned upside down. The modern design philosophy is: system should be designed and not the user to fit the system, and users' characteristics are as much design requirements as functional requirements, performance requirements. This is how user centred design was codified and formalised and is now in international standards, e.g. the human centred design process for interactive systems in ISO 9241-210 has explicit requirements for understanding the user, task and environment, user involvement in the design and development process, an iterative process guided by user-centred evaluation and the use of multidisciplinary skills and perspectives.

The turn around has an economic and moral impact. If a product or service isn't easy to use, it's an expense to the business in the form of calls to support, training, lost sales, data entry errors, injuries and deaths, to name a few. A key argument for continually evaluating early in the process rather than in usability testing at the end of the acceptance process is that defects in the interaction design after they have been released are many times more expensive than defects found during the requirements and prototyping process.

1.2.3 The Contemporary Context in India

The study is carried out in a national setting with questions which are particularly urgent. It is one of the quickest growing of all the times in Indian history. In the past 15 years or so, the internet has progressed from being a small minority of urbanites to the majority of people and then mobile – the vast majority of people. The gradual shift of functions like government services, banking, identity

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verification, taxing, welfare distribution, education, health records etc. to digital services. The amount of business transacted over digital payment systems is amongst the highest in the world.

There's 45 people in the room and what an enormous number of first generation technology people we have there – not necessarily well educated, often working in a language other than the language of the interface, often with a small screen, low cost device, flaky internet connection. For this population, an interface which makes the assumption that it is already familiar with the conventions of computing is not simply a nuisance, but exclusionary. But when it comes to a welfare entitlement, a school admission or a medical record, an unusable interface has a civic impact.

Several aspects of this context are different from that of most of the international HCI literature. The number of devices is large: The service should cater for low memory, low resolution screen, outdated operating systems, on high-end devices and on the latest flagship devices. Not only are hefty interfaces slow, they are costly to the user, as well, because of variable connections and metered connections. Linguistic Diversity: no one interface language is acceptable to the population, and transliteration, script rendering and text expansion causes layout issues, which are not addressed in English designs. Devices are often shared, and it's not possible to make assumptions of persisting sessions, credentials and private information displayed on the screen. Popular: assisted use – another person (relative, service centre operator, shop keeper) supports the user in his/her activities, there are 2 persons with different needs, issues that single use design does not take into account, issues of privacy.

The empirical part of the present study is located in just this context. It examines a public service portal (existing on-line and mobile) and a mixed population of digital literates, and considers what the interaction failures are, why they are occurring and what design solutions have been shown to reduce interaction failures.

1.3 Conceptual Foundations of the Field

HCI is conventionally analysed in terms of four interacting elements: the human, the computer, the interaction between them, and the context in which the interaction is situated. A brief account of each establishes the vocabulary used throughout this thesis.

1.3.1 The Human

The human being involved in an interactive system is not a theoretical abstraction; it is an organism with a perceptual, cognitive and motor design and with measurable perceptual, cognitive and motor abilities, and a design which doesn't take these abilities into account will not work predictably.

Perceptually, human vision only has high acuity within a rather small foveal vision area of around two degrees, and thus visual hierarchy and scanning-pattern decide what is actually seen on a screen. In most people colour perception is trichromatic, but in about 8% of males it is significantly altered – for this reason colour should never be the only means of conveying critical information. Auditory perception does not have a directionality restriction, so as a means of alerting it is good but as a

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means of continuous information it becomes intrusive. Haptic feedback gives feedback without requiring visual attention, and it is because of this that it has become the core of touch interaction.

Cognitively, the constraint of overriding practical importance is the limited capacity of working memory, classically thought of as being 7 items (Miller 1956) and even fewer by later research (closer to 4 chunks). Screen to screen interfaces that ask people to remember information will create mistakes when some distraction occurs. The menu, the icon and the visible option list are based on the psychology of long-term memory which is effectively unlimited, but it is much more reliable for recognition than for recall. Attention is selective and serial, for demanding tasks, and the "illusion of multitasking" is usually a rapid switching of tasks, with a cost on each switch.

Fitts's law is used to describe motor performance in pointing tasks, and suggests that the time to acquire a target is proportional to the logarithmic ratio between distance and target width. One of the few truly quantitative predictive model tools available to an interface designer is the law and it has a few implications that are worth discussing: screen edges and corners are important, small target sizes lead to errors, and frequently used controls should be large and near the resting position of the hand or cursor.

Design should embrace more than just deplore another aspect of human error. The difference between slips and mistakes is relevant to the design of interfaces. Slips are errors which happen when the goal is right but the performance is wrong, such as the user selecting the wrong option in a familiar sequence or selecting the next door in a menu; they may be due to fatigue, distraction and automaticity and can be remedied by confirmation of destructive actions, large target sizes, and reversibility. A mistake is a failure to execute an intention that is wrong, typically because the user's mental model of what the system is and how it works is wrong; mistakes are not dealt with by asking the user to confirm that they are correct, as they will surely respond with confidence that they are, but rather by making the system communicate more clearly regarding its state and its conceptual structure. Warning and penalty-interface for carelessness treats most errors as carelessness, miss-diagnosing most errors.

People are different from one another, too. Their age, past experience, language, education, cultural expectation and ability vary. In any large population, there is a significant number of individuals with visual, auditory, motor and cognitive impairments, and design based on the unimpaired young adult as the typical user leaves out a large number of people unnecessarily. As the years go by, visual acuity, contrast sensitivity, fine motor skills and the speed of information processing decrease, and being cautious and fearing uncertainty are often increased. The conventions used by the interface are obvious or arbitrary, depending on their previous experience; if the user has never seen such a hamburger menu before, the three horizontal lines are not necessarily understood as an invitation to action. Competence in language is not only important for translation, it also plays a role in the interpretation of the text of instruction which is presented at a level well above the reading level of the intended audience. These variations are not “fringe” factors that can be dealt

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with once the main design is agreed, but in the population under investigation in this thesis these are the factors which determine the success or failure.

1.3.2 The Computer

The computational side of the interaction comprises input devices, output devices and the software that mediates between them. Input has diversified from keyboard and mouse to touch, stylus, speech, gesture, gaze, and physiological sensing. Output has diversified from character display to high-resolution graphics, synthesised speech, haptic actuation, and immersive stereoscopic rendering. Each modality carries distinct properties: speech is fast for expression but poor for precision and unusable in many social settings; touch is direct and learnable but imprecise and prone to occlusion; gesture is expressive but fatiguing and difficult to discover.

Of equal importance are the properties of the system that the user cannot see but must nonetheless reason about: response latency, error handling, state persistence, network dependence and the model of the world the software maintains. Perceived responsiveness follows well-established thresholds, with delays below roughly one tenth of a second experienced as instantaneous, delays of about one second preserving the flow of thought, and delays approaching ten seconds exhausting attention and requiring explicit progress indication if the user is to remain engaged.

1.3.3 The Interaction

The only way to convert human intentions into action of the system, and the state of the system into human understanding is through interaction. The most influential is that of Norman (1986) that described seven stages involved in the development of a goal, the formation of an intention, the specification of an action sequence, the execution of the action sequence, the perception of the resulting system state, the interpretation of the system state and the evaluation of the outcome against the original goal. The two gulf the model highlights as difficulty are the gulf of execution (how much it is different to what the user wants to do) and the gulf of evaluation (how different it is from what the user can see and understand).

Indeed, most (all but a handful) of the usability issues studied in this thesis can be considered problems of this nature. If a user doesn't know what function to use to get the desired effect then the gap of execution is too great. If the user performs an action and receives no feedback as to the success or failure of the action, then the gulf of evaluation is too big. The answers to the design problems are obvious: "show actions possible" and "show state of the system so that is perceptible and interpretable in the user's terms.

The theories of affordance, signifier, constraint and mapping can be used to support Norman's theory and how an interface, or interface model, communicates to the user how it is used. Affordance is a relation between the properties of an object and the capabilities of the agent that determines how the object can be used; in the case of screen interfaces, where the properties are not real, but simulated, the relation of interest is the signifier – the perceptible aspect of the object that tells you where you can act. If a control is in the interface, but cannot be interacted with and doesn't contain a

signifier, it won't be perceived in practice. Constraints limit the options, and consequently reduce the potential for errors, like only being able to enter valid dates into a date field or only enter correct data into the form before it is submitted. The mapping is the mapping between the controls (or manipulanda) and their effect; natural mapping, which maps the arrangement of the controls over the arrangement of the things to which the controls refer, brings the mapping to almost zero.

The loop is completed by providing feedback. The effects of each action should be obviously related to the action and the amplitude of the effect should correspond to the amplitude of the action: small but clear for everyday actions, big but sharp for more serious actions. One of the common grounds for non-receipt of a feedback is duplicate submission, as the person who doesn't receive any feedback saying that the payment or application has been taken, assumes that it did not go through, and tries again, thus making the exact same mistake which was supposed to be avoided because of the careful design of the transaction.

A second concept, which is also important, is an internal model which a user has of how a system works—the so-called mental model. Mental models are incomplete, unstable, partly wrong but they are at the basis of the prediction of how the system behaves. When the model the system suggests when using it is the same as the user's, the user can make sure in interacting with the system without being afraid of making mistakes. Many aspects of interface design are about communicating the right (and helpful) abstraction of the system through the positioning of the interface elements.

1.3.4 The Context

Interaction always takes place in a context. This can happen in a physical setting, with specific lighting, noise and stability; a social setting, with expectations regarding attention and privacy; and an organisational setting, with rules, procedures and incentives; and a cultural setting, where the meaning of symbols, colours, reading order and forms of address are understood. Design that works in a tranquil laboratory under ideal conditions can be rendered useless in crowded trains, in the bright glaring sunlight or in a line-up at some public office as other people wait and watch.

The physical aspects of context have grown in significance in the context of the mobile transition, instead of diminished. A desktop interface might be a seated user, a steady light, a large screen and an accurate pointing device and a user's attention. None of these can be assumed to be a mobile interface. The user can be standing, moving while using, holding the device in one hand, operating the device with a thumb that only reaches a portion of the screen, in glare that makes it difficult to see low-contrast text, and can be looking at the display while engaging in other tasks. There are many interruptions and restarts of interaction which value the preservation of the state and interfaces that clearly indicate where the user was.

Social is also significant in the context of this study. In a public setting and/or in the presence of others, information that would otherwise be private in a single-user model becomes public. Whereas interfaces that show the sensitive information by default, or where users have to speak the confidential information, create a dilemma of do or don't do, and risk or don't risk privacy. In this

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study, contextual factors are thus not regarded as "noise" to be "controlled" out of the design, but rather design parameters in themselves.

1.4 The Interdisciplinary Character of HCI

HCI is based on a collection of disciplines that would typically not be found together in any one research programme. Computer science provides the design of the interactive systems, the algorithms that enable the systems to be responsive to interaction, and the software engineering practice in which the design is implemented. Models of perception, memory, attention, learning and error provided by cognitive psychology. The physical aspect is covered by Ergonomics and human factors, from anthropometry to workload and fatigue. Design is an attitude and a skill in the field of visual communication, information architecture and prototyping. The study of technology in use is provided by the disciplines of sociology and anthropology, especially in the context of collaboration and organisations. Linguistics provides the information that is the basis for conversational and speech interfaces. The ethical and legal aspects give direction to privacy, consent, autonomy and inclusion.

This width adds strength, and difficulty. It allows the field to address problems that can't be defined by any single discipline, but also a literature that isn't easily comparable due to the problems of control in experiment, ethnographic observation and engineering critique and demonstration. A finding by controlled experiment with 20 subjects performing artificial tasks is a finding of comparable weight as a finding by 6 months observation of the workplace and both are used as evidence for design recommendations without any indication of the relative weight of the findings. The methodological position adopted in this thesis (as expressed in Chapter 4) is a reaction to this condition, since it does not either take the quantitative or the qualitative evidence as being superior, but attempts to integrate both, and to identify what each strand of evidence can support.

The interdisciplinary aspects of the field have implications for practice, too. Within a development organisation, there are typically not one or two people that take ownership of interaction design. It's shared among product managers, who create the list of what it should do; visual designers, who determine its appearance; developers, who implement its functionality; content writers, who determine the words that a user will see; and quality assurance (QA) workers, who determine what is a defect. Usability failure does not tend to be due to failure of any one of these roles, but because of the lack of continuity between them, a lack of a common framework so that what seems sensible in one specialty gives problems with what seems sensible in another. Each principle has been assigned to the role and stage in which it can be realistically implemented and the framework outlined in Chapter 7 is based on this allocation.

1.5 Motivation for the Study

The impetus to this study is the noted inequality of maturity of HCI knowledge and the quality of the systems that people experience. The discipline has a significant base of principle which is well validated. It has a clear system of evaluation and does not need the use of special equipment. Its main conclusions about memory limitation, error causation, feedback and consistency have remained

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constant over the past decades and are not under serious challenge. But a citizen who wants to renew a document or assert an entitlement or make an application over the official information technology system routinely comes across interfaces that breach these principles in fundamental ways, and does so with the issue that, if one chooses a competitor, there is no one else to do these sorts of things because these are essential services.

The second motivation has to do with the nature of the evidence base. The people most in need of the interaction design being done right are the ones most underrepresented in the research that's used to guide interaction design – those with limited education, limited prior experiences with computing, limited devices, limited connectivity. Where they do show up in literature, such users are often described as a special case, in which they need simplified versions of things, rather than as a set of users who are demonstrating that the design is broken and everyone suffers, but those who are more experienced with the design just muddle through without comment. The present study takes the opposite point of view: that the errors that are exposed by unskilled users are, for the most part, not errors of the user, but errors in the design.

1.6 Statement of the Problem

Interactive systems have been around for 50 years, and, despite the creation of numerous design principles and assessment techniques, they continue to flop in well-known ways. The failures are not that unusual nor are they new. These encompass all the same types of problems that the literature reported on 30 years ago: navigation schemes that are focused on the organization rather than the user tasks; terms used in forms that are not the same language as the users, and which don't respond to the users' input unless they are marked as an error; too late, ambiguous or even missing feedback; varying the layout and labelling of forms across different parts of the same product and/or between the on-line and mobile versions of the same service; and accessibility provisions that are missing or a 'checkbox exercise'.

These remains failure assuming that there is a gap; it is not just a knowledge gap. The principles are available as written material. What is missing is the link between the abstract principles, which are articulated at a high level and have low applicability, and the decisions the designer has to make; between evaluation methods that are created in a lab, and the constraints and time pressures of the development process; and between usability being considered an activity to test at the end, and the property being designed in from the start and being developed together with the digital literacy population.

There are a number of structural conditions to support the gap. The answers to the implementation questions (data model, the flow of transactions, the vocabulary, etc.) are decided at a very late stage in the development process and the interface tasks are delegated at the end of the project, when the designer has to accommodate the controls in an architecture that clashes with the user's task structure. Requirements are most often identified by institutional stakeholders who will tell the story about how they believe it should be in the institution, not users who will be forced to live the process who can't tell the story of it. Where it is used, it often is only used in an acceptance test to see if the

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system works as described by the functional specification, and thus it doesn't say anything about whether there is a way to get the system to work. Often, members of the development organization and/or a population of convenience (very digitally competent members of the target group) are tested with the same usability test, with positive results on a systematic basis.

This is even more pronounced with regard to the provision of public services, under a new and fast-paced digitalisation. A business site that convinces a customer that it's "unusable" so that he doesn't buy it could be a public service site that denies a citizen a right to something because he can't make it "usable. The problem this research seeks to solve, is hence the following: What are the practical, measurable and actionable ways of applying existing HCI principles to increase usability, accessibility and UX for different user groups using vital digital services, on web and mobile platforms?

1.7 Aim of the Study

The aim of this study is to examine the principles and techniques of Human–Computer Interaction and to determine how user-centred design can be applied systematically to develop interactive systems that are effective, efficient, accessible and satisfying for diverse users, culminating in an empirically validated framework for interaction design in the context of essential digital services.

1.8 Objectives of the Study

The specific objectives of the study are as follows:

1. To examine the fundamental concepts, theoretical models and principles of Human–Computer Interaction, and to trace their historical development.
2. To study the principal types of user interface and interaction technique, and to compare their characteristics, strengths and limitations.
3. To examine the constructs of usability and user experience, their component dimensions, and the instruments through which they are measured.
4. To identify, classify and quantify the usability problems that occur in interactive applications delivered through web and mobile channels.
5. To study user-centred design methodologies and evaluation techniques, and to assess their relative diagnostic value and practical cost.
6. To examine the requirements of accessibility and inclusive interface design, and to assess conformance in the systems studied.
7. To analyse the influence of contemporary technologies, including mobile computing, voice interfaces and artificial intelligence, on the theory and practice of interaction design.
8. To develop, implement and empirically evaluate a redesigned interface based on user-centred principles, and to compare its performance against the existing baseline.

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9. To propose an integrated framework of HCI principles for the development of effective, accessible and user-friendly interactive applications.

1.9 Research Questions

The objectives are addressed through the following research questions:

RQ1: What categories of usability problem occur most frequently in the interactive systems examined, and what is their relative severity?

RQ2: How do measures of task performance, comprising completion rate, task time and error frequency, differ between the baseline system and a prototype redesigned according to user-centred principles?

RQ3: How do subjective assessments of usability and user experience differ between the baseline and the redesigned prototype?

RQ4: To what extent do user characteristics, including age, education, prior digital experience and device type, moderate the relationship between interface design and task performance?

RQ5: What is the conformance of the systems examined to established accessibility guidelines, and what is the effect of accessibility remediation on the wider user population?

RQ6: Which combination of evaluation methods yields the most complete diagnostic picture at acceptable cost, and how should they be sequenced within a development process?

1.10 Hypotheses

For the experimental component described in Chapter 5, the following hypotheses are formulated and tested:

H1: Task completion rates are significantly higher for the redesigned prototype than for the baseline system.

H2: Mean task completion times are significantly lower for the redesigned prototype than for the baseline system.

H3: Mean error counts per task are significantly lower for the redesigned prototype than for the baseline system.

H4: Perceived usability, measured by the System Usability Scale, is significantly higher for the redesigned prototype than for the baseline system.

H5: The magnitude of improvement associated with the redesigned prototype is significantly greater for participants of low prior digital experience than for participants of high prior digital experience.

1.11 Scope of the Study

The study covers the principal areas of Human–Computer Interaction, comprising user interface design, usability, user experience, interaction techniques and styles, user-centred design

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methodology, accessibility and inclusive design, prototyping, and usability evaluation. It treats interactive systems delivered through desktop web browsers and mobile applications, these being the channels through which the greater part of everyday interaction with digital services now occurs.

The empirical work is conducted on a public service portal accessible through both channels. Data are collected from adult users resident in India, sampled to include variation in age, educational attainment, prior digital experience and device type. Evaluation is conducted through expert heuristic inspection, a structured survey, controlled task-based usability testing, and automated and manual accessibility auditing.

The tasks selected for evaluation are drawn from the transactions that constitute the greater part of actual use: locating a specific service among the options presented, completing and submitting an application form, uploading a supporting document, checking the status of a pending request, and correcting an error in previously submitted information. These were chosen because they span the interaction types through which usability problems most commonly manifest, namely navigation and search, structured data entry, file handling, state enquiry and recovery from error. The last of these is treated as a first-class task rather than an exception path, on the grounds that error recovery is a routine part of real use and is among the least examined aspects of service interface design.

1.11.1 Delimitations

The study is delimited in the following respects. It does not address hardware ergonomics, industrial control interfaces, or safety-critical systems such as aviation and medical devices, each of which is governed by regulatory frameworks outside the present scope. It does not treat immersive virtual or augmented reality interfaces except by way of discussion of emerging directions. It does not conduct longitudinal study of adoption over extended periods, the evaluation being confined to task-based sessions and immediate post-task assessment. The redesigned artefact is a functional high-fidelity prototype rather than a production deployment, and inferences about long-term behaviour in live conditions are correspondingly limited. Finally, the study is conducted in a single national context, and generalisation to other cultural and infrastructural settings requires independent verification.

1.12 Significance of the Study

The significance of the study is theoretical, methodological and practical.

1.12.1 Theoretical Significance

The study contributes a consolidated account of HCI principles organised by their point of application in the design process rather than by their disciplinary origin. The existing literature presents principles in several partly overlapping collections, each internally coherent but expressed at differing levels of abstraction and derived from differing traditions of inquiry, with the consequence that a practitioner consulting them encounters redundancy at some points and silence at others. Organising the principle set by the design decision to which each applies converts a body of advice into an instrument of practice.

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The study further tests the predictive value of established models against behavioural data drawn from a population that is substantially under-represented in the international literature. The models of the interaction cycle, of mental model formation and of error causation were developed largely through observation of users in industrialised settings who possessed both formal education and prior computing exposure. Whether they describe with equal accuracy the behaviour of a first-generation mobile user attempting a welfare transaction in a second language is an empirical question that has attracted less attention than its importance warrants, and the present study addresses it directly.

1.12.2 Methodological Significance

The study provides comparative evidence on the diagnostic yield of heuristic evaluation, survey instrumentation, task-based testing and accessibility audit when applied to the same system by the same research programme. Practitioners are routinely obliged to choose among these methods under constraints of time and budget, and the guidance available to them consists largely of general characterisations of each method's strengths rather than of measured comparison. By recording which problems each method detected, which it missed, and at what cost in evaluator and participant hours, the study allows evaluation resources to be allocated on evidence rather than on convention.

1.12.3 Practical Significance

The study produces an integrated design framework, an annotated set of design patterns validated by measurement, and a documented redesign that demonstrates the effect of user-centred intervention on measurable task performance. These outputs are directly usable by designers and developers working on service delivery in comparable settings, and by institutions specifying requirements for such systems. For an institution commissioning a digital service, the framework provides a basis for stating usability requirements in verifiable terms at the point of procurement, which is the stage at which such requirements have the greatest leverage and are at present most commonly omitted.

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The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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